



OPERATING AND SERVICE MANUAL

MODEL 415B

SERIALS PREFIXED: 213-

STANDING WAVE INDICATOR

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275 AGE MILL ROAD, PALO ALTO, CALIFORNIA, U.S.A.



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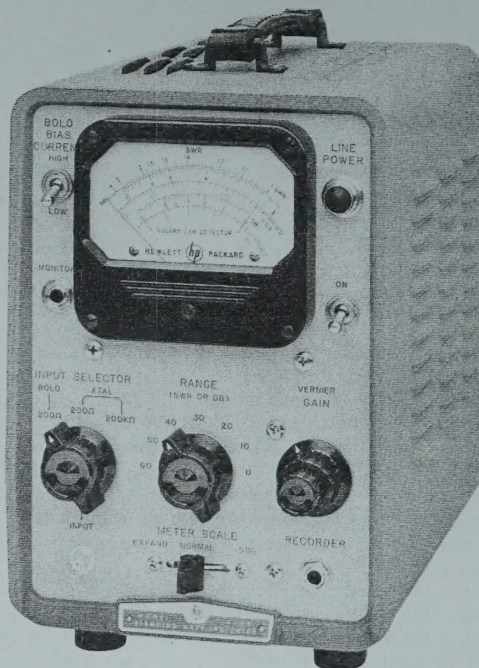


Figure 1-1. Model 415B Standing Wave Indicator

Table 1-1. Specifications

Frequency:

1000 cps $\pm 2\%$. Other frequencies 315 to 2020 cps available on special order. Should not be harmonically related to power line frequency.

Sensitivity:

0.1 μ volt at a 200-ohm level for full scale deflection.

Noise Level:

Less than 0.03 μ volt ref. to input operated from a 200-ohm resistor at room temperature.

Amplifier Q: 30 (nominal)**Calibration:**

Square law. Meter indicates swr, db.

Range:

70 db. Input attenuator provides 60 db in 10 db steps. Accuracy ± 0.1 db per 10 db step. Maximum cumulative error ± 0.2 db.

Scale Selector:

"Normal", "Expand", and "-5 db".

Meter Scales:

SWR 1-4, swr 3-10, expanded swr 1-1.3, db 0-10, expanded db 0-2.

Gain Control:

Adjusts to convenient reference level. Range at least 10 db.

Input:

"Bolo" (200 ohms). Bias provided for 8.7 ma bolometer or 1/100 amp fuse; or 4.3 ma low current bolometer.

"Crystal". 200 ohms for crystal rectifier. "200,000 ohms". High impedance for crystal rectifier as null detector.

Recorder Output:

Jack provided for recording milliammeter having 1 ma full scale deflection, internal resistance of 1500 ohms or less.

Input Connector: BNC**Power:**

115/230 volts $\pm 10\%$, 60 cps, 55 watts. Other frequencies on special order.

SECTION I

GENERAL INFORMATION

1-1 GENERAL DESCRIPTION

The Model 415B Standing Wave Indicator is a high-gain, tuned electronic voltmeter operating at a fixed audio frequency. It is designed primarily for use in making standing-wave measurements in conjunction with a suitable detector and slotted line or waveguide section. The Model 415B may also be used as a null indicator in bridge circuits and other applications requiring a sensitive fixed-frequency indicator. It is calibrated to indicate directly in SWR or in db when used with square-law devices such as crystal diodes (at low signal levels) and barretters. The Model 415B also has expanded scales for accurate reading of small increments.

Operating frequency of the Model 415B is determined by a single plug-in filter. The instrument is normally supplied for operation at 1000 cps $\pm 2\%$. The operating frequency may be changed in the field by installing a new plug-in filter tuned to the desired frequency. Plug-in filters for any single frequency between 315 and 2020 cps are available from the Hewlett-Packard Company; the frequency selected should not be harmonically related to the power line frequency.

1-2 INITIAL INSPECTION

After the instrument is unpacked, it should be inspected carefully for damage received in transit.

If any shipping damage is found, refer to the "Claim for Damage in Shipment" page in this manual.

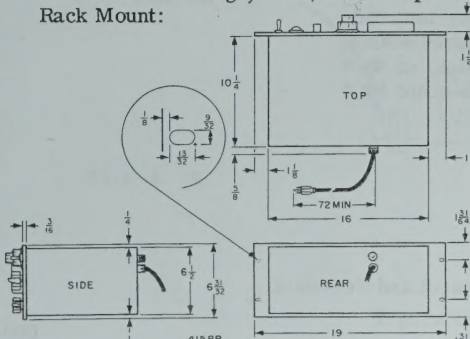
1-3 POWER CABLE

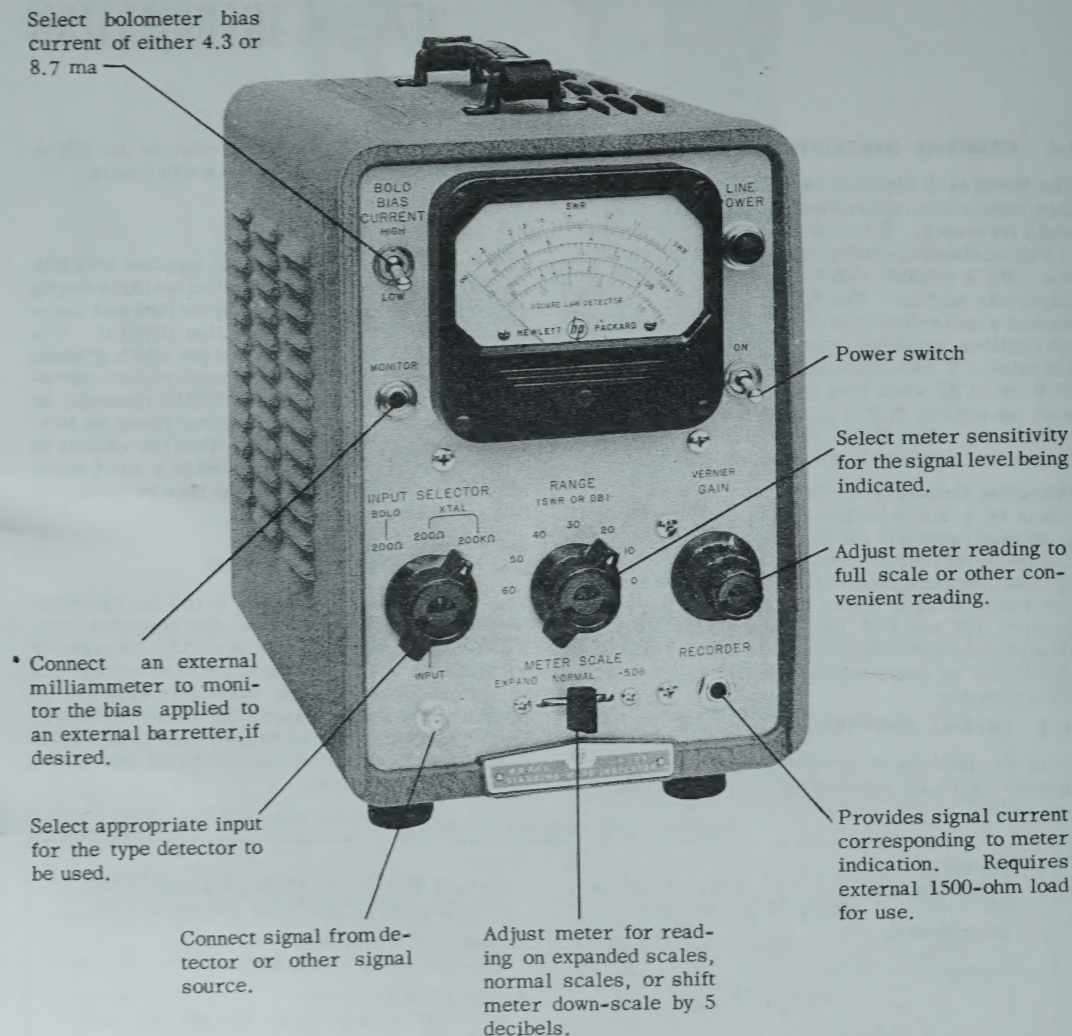
The three-conductor power cable supplied with this instrument is terminated in a polarized three-prong male connector recommended by the National Electrical Manufacturers' Association (NEMA). The third contact is an offset round pin which grounds the instrument chassis when used with an appropriate receptacle. To use this NEMA connector in a two-contact receptacle, a three-prong to two-prong adapter should be used. When the adapter is used, the round pin is terminated in a short green lead from the adapter which can then be connected to a suitable ground.

1-4 230-VOLT OPERATION

This instrument is normally wired for operation from a 115-volt power source. For operation from a 230-volt power source, the dual 115-volt primary windings on the power transformer are connected in series. Refer to the schematic diagram for proper connections. After converting the instrument, change the power line fuse to the size specified in the Table of Replaceable Parts (section V) for 230-volt operation.

Table 1-1. Specifications (cont'd)

<p>Dimensions:</p> <p>Cabinet Mount: 7-1/2 in. high, 11-3/4 in. high, 12-1/2 in. deep.</p> <p>Rack Mount:</p> 	<p>Weight:</p> <p>Cabinet Mount: Net 13 lbs., shipping 19 lbs.</p> <p>Rack Mount: Net 17 lbs., shipping 29 lbs.</p> <p>Accessories Furnished:</p> <p>41A-16E Cable Assembly</p> <p>Accessories Available:</p> <p>415B-42B Plug-in Filter 315-700 cps</p> <p>415B-42C Plug-in Filter 700-2020 cps</p> <p>AC-16K Video Cable Assembly, 4 feet of RG-58/U 50-ohm coaxial cable terminated at each end with UG-88/U Type BNC male connectors.</p> <p>AC-16D Cable Assembly, 44 inches of RG-58/U 50-ohm coaxial cable terminated at one end only with UG-88/U Type BNC male connectors.</p>
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MP-S-512B

Figure 2-1. Front Panel Control and Terminal

SECTION II OPERATING INSTRUCTIONS

2-1 CONTROLS AND TERMINALS

Refer to Figure 2-1 for explanation of the panel controls and terminals.

2-2 AUXILIARY EQUIPMENT REQUIRED

A typical test set up for making SWR measurements is shown in Figure 2-2. The auxiliary equipment required with the Model 415B follows:

A. SIGNAL SOURCE

The signal source should cover the desired frequency range and be amplitude modulated at the operating frequency of the Model 415B. Generally, squarewave modulation is used which reduces to a minimum the effects of harmonics and frequency modulation. If the signal source is pulse-modulated, the duty cycle should be not less than approximately 40%. Short pulse type signals or poor quality square waves can introduce measurement errors in the Model 415B.

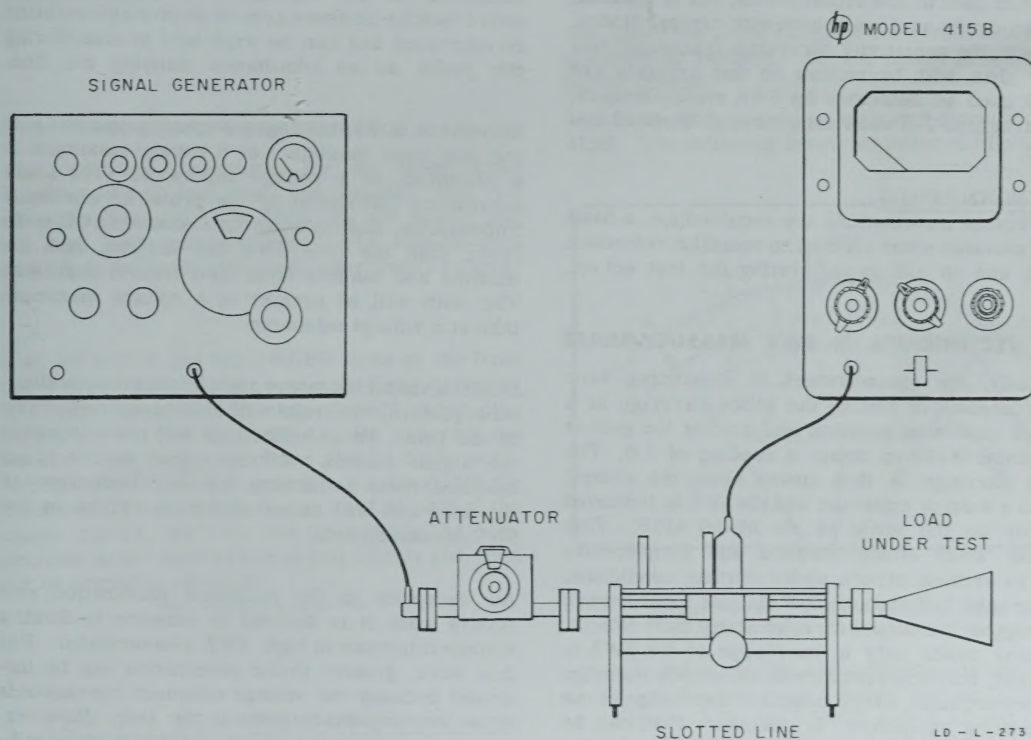


Figure 2-2. Test Setup

In many applications, it is necessary to minimize interaction between the oscillator and the load. In these cases, an isolating device should be used. For flexible and versatile operation, the signal source should indicate power output and should include an accurately calibrated attenuator.

B. CABLES OR WAVEGUIDES

The cable or waveguide used for connecting the source to a slotted section should match the source impedance over the desired frequency range.

C. SLOTTED SECTION

The slotted section should cover the desired frequency and be equipped with an accurate scale or indicator.

D. DETECTOR

The detector should be a square-law (output proportional to rf power input) device such as a barretter or a crystal diode operated at low signal levels. A barretter is reasonably square-law when used at low signal levels, but in general, this can not be said in all cases with crystal diodes. However, the sensitivity of crystals is considerably better than with barretters so that crystals are widely used as detectors for SWR measurements. See paragraph 2-5 when using crystal diode as detector.

E. KNOWN LOADS

Various terminations are required (i.e., a fixed and a movable short circuit) to establish reference points and to aid in calibrating the test set up.

2-3 TECHNIQUES IN SWR MEASUREMENTS

Basically, the measurement of a standing-wave ratio consists of setting the probe carriage at a voltage maximum position and setting the gain of the Model 415B to obtain a reading of 1.0. The probe carriage is then moved along the slotted line to a voltage minimum and the SWR is indicated directly on the scale of the Model 415B. This method, while straightforward and simple, may lead to serious errors under certain conditions. Paragraphs 2-4 through 2-9 discuss these errors and suggest techniques for minimizing their effects. In many cases only a knowledge of the SWR is required, but there are other cases, chiefly in design and development, where complete knowledge of the terminating equipment is desired. This can be obtained by measuring SWR and phase in the standing-wave pattern.

Generally, the impedance characteristic of the load is obtained by measuring the position of the voltage minimum. This position is compared to a shifted position of the voltage minimum which occurs when a known load replaces the load under test at a reference point on the slotted line. For convenience, the known load is usually a short circuit or shorting plate and the reference point is the load connection. The distance between these two minima is entered on a Smith Chart and the reactive component is determined. Detailed instructions for measuring the impedance characteristics of the load are given in paragraphs 2-10 through 2-13.

2-4 DETECTOR PROBE PENETRATION

A general rule in slotted line work is that the penetration of a sampling probe into the line should be held to a minimum. One of the major sources of error in SWR measurements is the failure to observe this rule.

The power extracted by the sampling probe causes distortion in the standing-wave pattern. This effect usually becomes greater as probe penetration is increased and can be explained by considering the probe as an admittance shunting the line.

Impedance in the standing-wave pattern varies along the line from maximum at a voltage maximum to a minimum at a voltage minimum. The shunt admittance introduced by the probe lowers these impedances, thus causing the measured SWR to be lower than the true SWR and shifting both the maxima and minima from their natural positions. The shift will be greater at a voltage maximum than at a voltage minimum.

Besides absorbing power and affecting the standing-wave pattern, the probe will also cause reflections in the line. These reflections will travel towards the signal source. If the signal source is not matched, these reflections are re-reflected toward the load and will cause additional errors in low SWR measurements.

An exception to the minimum penetration rule occurs when it is desired to examine in detail a voltage minimum in high SWR measurement. For this work, greater probe penetration can be tolerated because the voltage minimum corresponds to a low impedance point in the line. However, only at a voltage minimum can you tolerate substantial probe penetration.

2-5 PRECAUTIONS WHEN USING CRYSTAL DETECTORS

Whenever a crystal detector with a matched load resistor is used, the INPUT SELECTOR switch must be set at the XTAL-200K Ω position to obtain accurate square-law response. With an unloaded crystal, select the input impedance which gives maximum sensitivity. Usually the XTAL-200 Ω position will give the best sensitivity. However, some crystal diodes may give higher output in the XTAL-200K Ω position. Maximum sensitivity is desirable so probe penetration in the slotted line can be kept to a minimum.

There are precautions to be observed concerning all crystal detector elements. Crystal diodes exhibit a departure from the ideal square-law response for which the 415B is calibrated. This departure tends to occur when the rf power level exceeds a few microwatts. This corresponds to a reading of approximately fullscale on the 30-db range of the 415B with the gain controls set to maximum. In paragraph 2-7, methods of calibrating the detector are discussed.

2-6 OPERATING PROCEDURES

The operating procedures for the Model 415B Standing Wave Indicator are divided into two classifications (A) low SWR (10 and below) and (B) high SWR measurements. The step-by-step procedure for making these measurements follows:

Both MONITOR and RECORDER jacks on the front panel of the Model 415B receive the three-terminal 1/4 inch diameter "tip-ring-sleeve" phone plug supplied with the instrument. Do not use the standard single-circuit phone plug in these jacks. In both jacks the sleeve connection is grounded to the instrument chassis and is not used as part of the output circuit; the ring and tip provide the connections to the appropriate signal circuit and must not be grounded externally.

A. LOW SWR MEASUREMENTS (10 and below)

1) Turn instrument ON. For maximum stability allow approximately 10 minutes warm-up.

00040-3

- 2) Set INPUT SELECTOR switch for the type of detector that is to be used.
- 3) Connect the detector cable to the INPUT.
- 4) Set GAIN and VERNIER controls to approximately 3/4 maximum.
- 5) Set RANGE switch on 30-db or 40-db position. Adjust probe penetration to obtain up-scale reading.
- 6) Peak the meter by adjusting the modulation frequency of the signal source, if adjustable. Reduce probe penetration to keep meter on scale.
- 7) Peak the meter by tuning the probe detector, if tunable. Reduce probe penetration to keep meter on scale.
- 8) Peak the meter by moving the probe carriage along the line. Reduce probe penetration to keep meter on scale.
- 9) Adjust GAIN controls and/or output power from the signal source to obtain exactly full-scale reading.
- 10) Move the probe carriage along the line to obtain a minimum reading. Do not retune probe or detector circuit.
- 11) Read SWR, which is indicated directly on the 415B. The following examples refer to Figure 2-3.

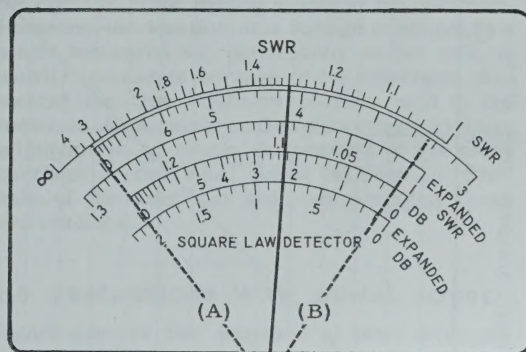


Figure 2-3. Detail of Meter Face

a. If the reading at the minimum is lower than 3 on the top scale (dashed pointer line A in Figure 2-3), set RANGE switch to next (40-db or 50-db) range and read the indication on the second SWR (3 to 10) scale. In Figure 2-3, the reading is 3.25 (dashed pointer line B).

b. If the RANGE switch is changed by two steps, use the top SWR scale; however, all indications on this scale must be multiplied by 10.

c. If the SWR is 1.3 or less, it can be read on the EXPANDED SWR or EXPANDED DB scale after the METER SCALE switch is set to EXPAND and steps 8, 9, 10 and 11 are repeated. In the EXPANDED position, set RANGE switch to next (40-db or 50-db) range and readjust GAIN control to obtain a reading of full-scale at the voltage maximum.

d. The standing-wave ratio may also be expressed in decibels using the DB and EXPANDED DB scales. If the SWR is between 5 and 10 on the DB scale, set METER SCALE switch to -5DB and set RANGE switch to next lower (CCW) range. To obtain a true reading, subtract 5 db from the indication on the DB scale.

A graph of SWR in decibels vs. voltage standing-wave ratio is shown in Figure 2-4.

For accurate measurements, it is good practice to take several readings with different amounts of probe penetration to detect any probe loading error in the standing-wave pattern.

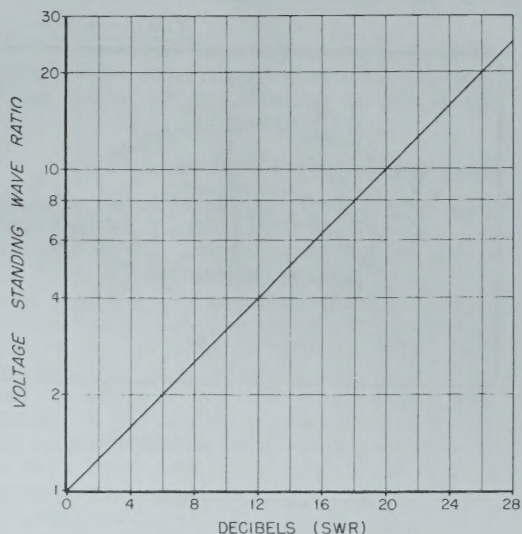


Figure 2-4. Graph Showing Standing Wave Ratio in DB vs. SWR

B. HIGH SWR MEASUREMENTS (above 10)

The straightforward measurement of SWR with conventional methods is generally applicable when measuring nominal SWR's up to 10, but at higher SWR's special techniques are desirable.

When the SWR is high, probe coupling must be increased if a reading is to be obtained at the voltage minimum. However, at the voltage maximum this high coupling may result in a deformation of the pattern, with consequent error in reading. In addition to this error caused by probe loading, there is also danger of error resulting from the change in detector characteristics at higher rf levels.

C. DOUBLE MINIMUM METHOD

In the double minimum method, it is necessary to establish the electrical distance between the points where the output is double the minimum (see Figure 2-5).

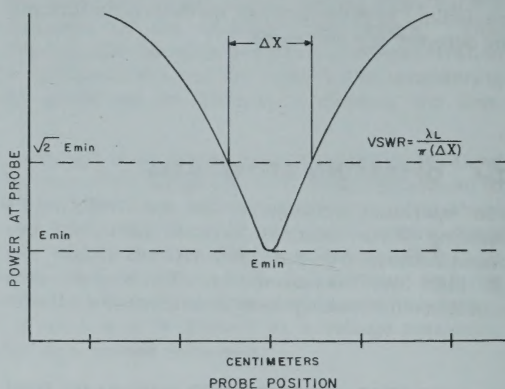


Figure 2-5. Graph Showing Double Minimum Method for Computing SWR

1) Repeat steps 1 through 7 in the Low SWR Measurement procedure.

2) Move the probe carriage along the line to obtain a minimum reading and note the probe carriage position.

3) For reference, adjust gain controls to obtain a reading of 3.0 on the DB scale. If a linear detector is being used, adjust GAIN controls for an indication of 1.5 on the DB scale.

- 4) Move the probe carriage along the line to obtain a reading of full-scale ("0") on the DB scale on each side of the minimum.
- 5) Record as d_1 and d_2 , the probe carriage positions at the two equal readings obtained in step 4.
- 6) Short the line and measure the distance between successive minima. Twice this distance is λ_L , the guide wavelength.

The SWR can then be obtained by substituting this distance into the expression:

$$SWR = \frac{\lambda_L}{\pi(d_1 - d_2)} = \frac{\lambda_L}{\pi(\Delta X)}$$

Where λ_L is the guide wavelength; d_1 and d_2 are the locations of the twice-minimum points.

This method overcomes the effect of probe loading since the probe is always set around a voltage minimum where larger probe loading can be tolerated. However, it does not overcome the effect of detector characteristics.

D. CALIBRATED ATTENUATOR METHOD

Another method for measuring high SWR's is to use a calibrated variable rf attenuator between the signal source and the slotted line. Adjust the rf attenuator to keep the rectified output of the crystal diode equal at the voltage minimum and voltage maximum points. The SWR in db is the difference in the attenuator settings.

- 1) Repeat steps 1 through 7 in Low SWR Measurements procedure.
- 2) Move the probe carriage along the line for a voltage minimum, adjust the rf attenuator to give a convenient indication on the meter, and note the rf attenuator setting.
- 3) Move the probe carriage along the line to a voltage maximum, adjust the rf attenuator to obtain the same indication on the meter as established in step 2, and note the rf attenuator setting.
- 4) The SWR may be read directly (in db) as the difference between the first and second readings.

While this method overcomes the effect of detector variations from a square-law characteristic, the effect of probe loading still remains. Be careful; always use minimum probe penetration.

2-7 CHECKING OF SQUARE-LAW RESPONSE

The square-law response of either a crystal diode or bolometer is easily checked with slotted line equipment.

A simple method of calibrating a detector is by increasing the power level in the slotted line in known steps and noting the detector response on the Model 415B.

Another method for calibrating a detector is to use a load having unity reflection coefficient (usually a short circuit). This load will then set up an electric field between adjacent minima in the slotted line closely approximating half a sine wave, thus giving a relative voltage that is a known function of the probe carriage position.*

Any new crystal being used for the first time should be checked, as there is often a significant variation between crystals. Data should be taken in both XTAL positions on the Model 415B, so that the better setting may be determined for any individual crystal diode.

2-8 LOCATION OF VOLTAGE MAXIMUM OR VOLTAGE MINIMUM

From the discussion on probe loading it has shown that it is more desirable to locate the voltage minimum than the voltage maximum since the effect of probe loading is less at the minimum. However, the location of a voltage minimum by a single measurement, particularly on low SWR, is usually inaccurate because of its broadness, thus making the true minimum position hard to determine. An accurate method of locating the voltage minimum is to obtain the position of the probe carriage at two equal output readings on either side of the minimum and then averaging these two readings.

2-9 PRECAUTIONS WITH SIGNAL SOURCES

Signal sources can introduce at least three undesirable characteristics that will affect slotted line measurements. These include presence of rf harmonics, frequency modulation, and spurious signals. Signal sources used for standing wave measurements should have relatively low harmonic content in their output. The standing wave ratio

*Ginzton, Edward L, "Microwave Measurements", pp. 142-144, McGraw-Hill Book Company, Inc., New York, N.Y. 1957

at a harmonic frequency may be considerably higher than at the fundamental. Spurious frequencies in the signal source are also undesirable, for, unless very slight, they will obscure the minimum points at high SWR values. Figure 2-6 shows plot of an SWR pattern made with signal source producing unwanted fm.

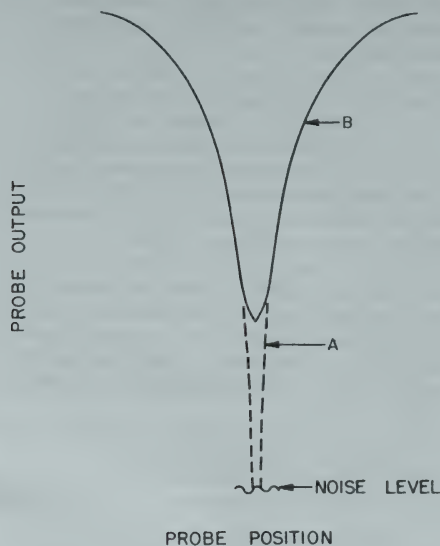


Figure 2-6. High Standing Wave Ratio Pattern
(A) Free of FM
(B) With Moderate FM

Instances are common where the presence of rf harmonics has led to very serious errors in SWR measurements. Such harmonics are usually present to an excessive degree only in signal sources that have coaxial outputs. Coaxial pickups of a broad-band type will often pass harmonic frequencies with greater efficiency than the fundamental. In waveguide systems, signal sources such as internal cavity klystrons have a more or less fixed coupling and in addition do not have pickups extending into the tuned cavity to cause perturbations of the cavity fields. Consequently, the harmonic problem is generally limited to coaxial systems. Harmonics become especially troublesome when the reflection coefficient of a load at a harmonic frequency is much larger than at the fundamental frequency--a common condition. When the harmonic content of the signal source is high, the large reflection coefficient of the load at the harmonic frequency can cause the harmonic standing wave fields to be of the same order of magnitude as the fields at the fundamental frequency.

Thus, a device having a SWR of 2.0 at the fundamental frequency will often have a SWR of 20 or more at the second harmonic frequency. If such a device is driven from a signal source having, say, 15% second harmonic content, the peaks of the standing waves of second harmonic will be about one-fourth the amplitude of the peaks at the fundamental frequency. Figure 2-7 shows a typical SWR pattern obtained when the rf signal contains harmonics.

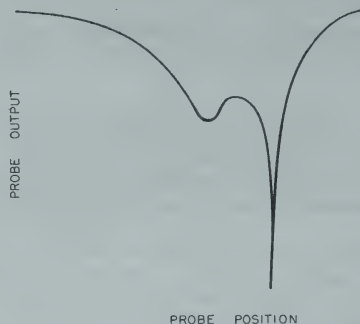


Figure 2-7. Typical Pattern of High SWR Spurious Frequency in Signal Source

2-10 IMPEDANCE MEASUREMENT RULES

Some rules of thumb that are helpful in making slotted line measurements are:

- 1) The shift in the minimum when the load is shorted is never more than \pm one-quarter wavelength.
- 2) If shorting the load causes the minimum to move toward the load, the load has a capacitive component.
- 3) If shorting the load causes the minimum to shift toward the generator, the load has an inductive component.
- 4) If shorting the load does not cause the minimum to move, the load is completely resistive and has a value Z_0/SWR .
- 5) If shorting the load causes the minimum to shift exactly one-quarter wavelength, the load is completely resistive and has a value of $Z_0 \times \text{SWR}$.
- 6) When the load is shorted, the minimum will always be a multiple of a half-wavelength from the load.

Shifts in voltage minima resulting from various types of loads are illustrated in Figure 2-8.

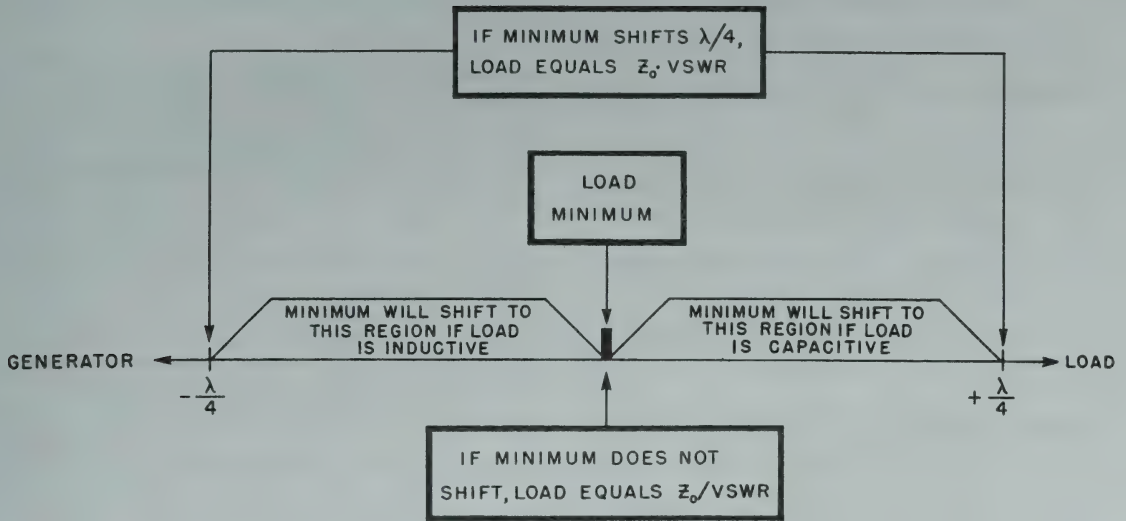


Figure 2-8. Summary of Rules for Impedance Measurement

2-11 IMPEDANCE MEASUREMENT PROCEDURE

The technique for performing actual impedance measurement is as follows:

1) Connect the load under test to the slotted section and measure the SWR and the position of the minimum in the standing wave pattern.

2) Replace the load with a short at the load end of the slotted line.

3) Determine the new minimum position with the line shorted.

4) The normalized load impedance may be computed by the formulas below. Refer to Figure 2-9.

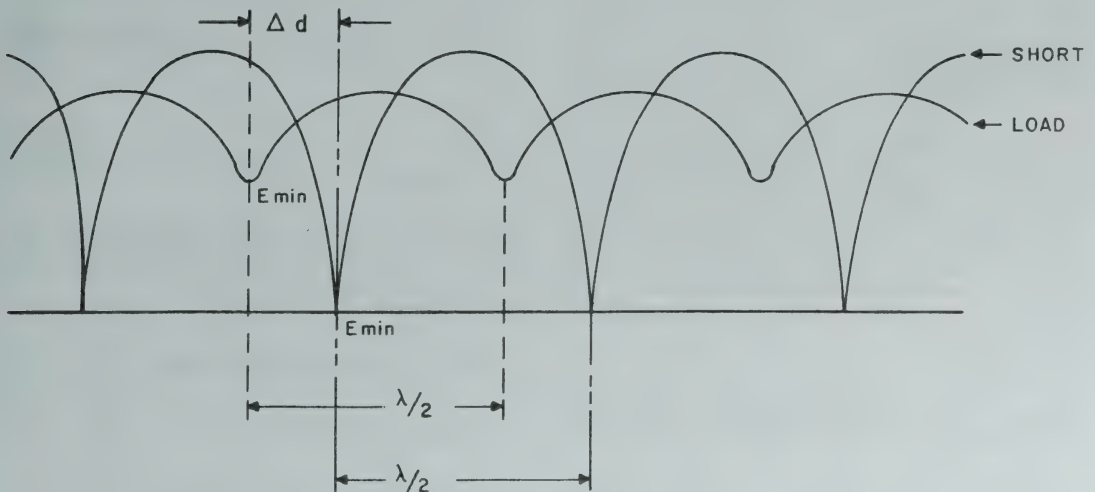


Figure 2-9. Graph Showing Standing Wave Patterns with a Load and Short

$$z_L = \frac{1 - j(\text{SWR}) \tan X}{(\text{SWR}) - j \tan X}$$

$$\text{Where: } X = \frac{180^\circ (\pm \Delta d)}{\frac{\lambda}{2}}$$

And: $\pm \Delta d$ = Shift in centimeters of the minimum point when the short is applied.

Δd takes a positive (+) sign when the minimum shifts toward the load.

Δd takes a negative (-) sign when the minimum shifts toward the generator.

$\frac{\lambda}{2}$ = One-half line or guide wavelength. It is the distance in centimeters as measured between two adjacent minima.

These calculations are based upon the assumption that no losses occur in the transmission system. For laboratory set-ups where the line lengths are short this assumption is customary. It is also assumed that the Z_0 for the lines is entirely resistive.

2-12 IMPEDANCE MEASUREMENT AND THE SMITH CHART

When data is obtained from slotted line measurement, one of the most indispensable tools and certainly the simplest to use, is the Smith Chart. This chart represents an impedance coordinate system so arranged that the variable quantities in impedance relationships are conveniently displayed for the solution of transmission line problems.*

The values of resistance and reactance shown on the Smith Chart in Figure 2-10 are based upon the normalized values. The normalized impedance, resistance or reactance is obtained by dividing the actual value by the characteristic impedance of the line. For example, if the actual impedance of a 50 ohm transmission line were found to be 100 ohms at some point, the normalized impedance would be 2.

The circles on the Smith Chart tangent to bottom of the chart are circles of constant and normalized resistance.

The straight line forming the vertical diameter of the chart is the line of zero reactance. To the right and left of this line are seen lines which curve away from the zero reactance line. The curved lines to the right are the lines of positive reactance $\frac{+jX}{Z_0}$.

The curved line to the left are the lines of negative reactance, $\frac{-jX}{Z_0}$.

For example, the impedance point of a line terminated by its characteristic impedance would be the center of the chart (with a normalized resistance of 1.0 and no reactive component).

In another example of actual impedance calculation:

$$Z_L = 5 + j25 \text{ ohms}$$

Normalized for a 50 ohm line would be:

$$z_N = 0.1 + j0.5$$

2-13 PROCEDURE FOR SMITH CHART CALCULATIONS

The step by step procedure for employing the Smith Chart when solving transmission line problems is outlined below. It should be understood that there are various methods employed for entering the Smith Chart with data obtained from the slotted line, and that the method outlined in this section has been found practical and simple.

- 1) Set up slotted line in system.
- 2) Measure SWR in manner described in section 2-6.
- 3) Determine wavelength of transmission line (λ_L). The distance as measured on slotted line between two adjacent minima is equal to one-half the wavelength of the line.
- 4) Find a convenient minimum point.
- 5) Replace load with short.
- 6) Measure Δd (the shift in centimeters of the minimum point with the short applied).

*Smith, P.H. "Transmission-line Calculator" Electronics, Jan. 1939, McGraw Hill.

- 7) Determine the number of wavelength of shift ($\Delta\lambda$).

$$\Delta\lambda = \frac{\Delta d}{\lambda L}$$

- 8) Starting at center of Smith Chart draw circle with SWR as radius. Read SWR on zero reactance line down from center.

- 9) Enter the Smith Chart at the top and proceeding in a direction of probe movement (either toward the load or toward the generator) when the load was replaced by a short to the quantity $\Delta\lambda$ established in step 7.

- 10) Draw a line to the center of the chart from the $\Delta\lambda$ point.

- 11) The intersection of this line and the SWR circles is the normalized impedance.

- 12) It is important that the convention be followed of first finding the minimum reference with the load on the line and then sliding the probe to the new minimum when the line is shorted. Should it be necessary to establish the shorted minimum point first, the Smith Chart would be entered with $\Delta\lambda$ in a direction opposite to the direction of probe movement. That is, the probe movement toward the load would be entered on the chart in a direction toward the generator.

- 13) The following is an example to clarify the previous procedure (refer to figure 2-10):

The SWR measured is 3.3.

Distance between two adjacent minima is 15 cm. Therefore, wavelength of the line is 30 cm (λL).

A convenient minimum is located at 22 cm.

When the line is shorted the minimum point shifts to 19 cm (toward generator).

$$\Delta d = 22 - 19$$

$$\Delta d = 3 \text{ cm}$$

$$\Delta\lambda = \frac{\Delta d}{\lambda L}$$

$$\Delta\lambda = \frac{3}{30}$$

$$\Delta\lambda = 0.1 \text{ wavelength}$$

Construct SWR circle on Smith Chart (1).

Construct radius to wavelength shift point (2).

Read normalized impedance at intersection of circle and radius (3).

In this example the normalized impedance is $0.44 + j0.63$. Assuming a characteristic impedance of 50 ohms, the load impedance, Z_L , is:

$$Z_L = 50 (0.44 + j0.63)$$

$$Z_L = 22 + j31.5 \text{ ohms}$$

2-14 USING THE 415B WITH AN OSCILLOSCOPE

With the 415B RECORDER jack at normal there is a 1500-ohm resistor (R37) across the tip and ring leads of the jack. With a plug in the jack, R37 is open. For proper operation of the 415B, therefore, it is necessary to connect a 1500-ohm resistor across the tip and ring of the plug when connecting the 415B to a high-impedance instrument like an oscilloscope.

Use a three-conductor plug, such as a Switchcraft No. 60, and connect a 1500-ohm 1/4 watt resistor across the tip and ring terminals (see Figure 2-9A). Be sure the resistor is not connected across the tip and sleeve (ground); if the external 1500-ohm resistor is connected to ground, part of the meter feedback circuit will be shunted to ground.

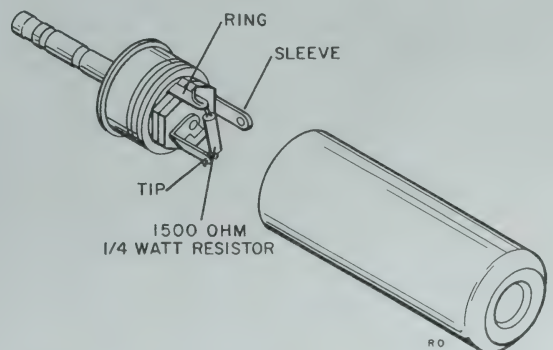


Figure 2-9A. Three-Conductor Plug Connection

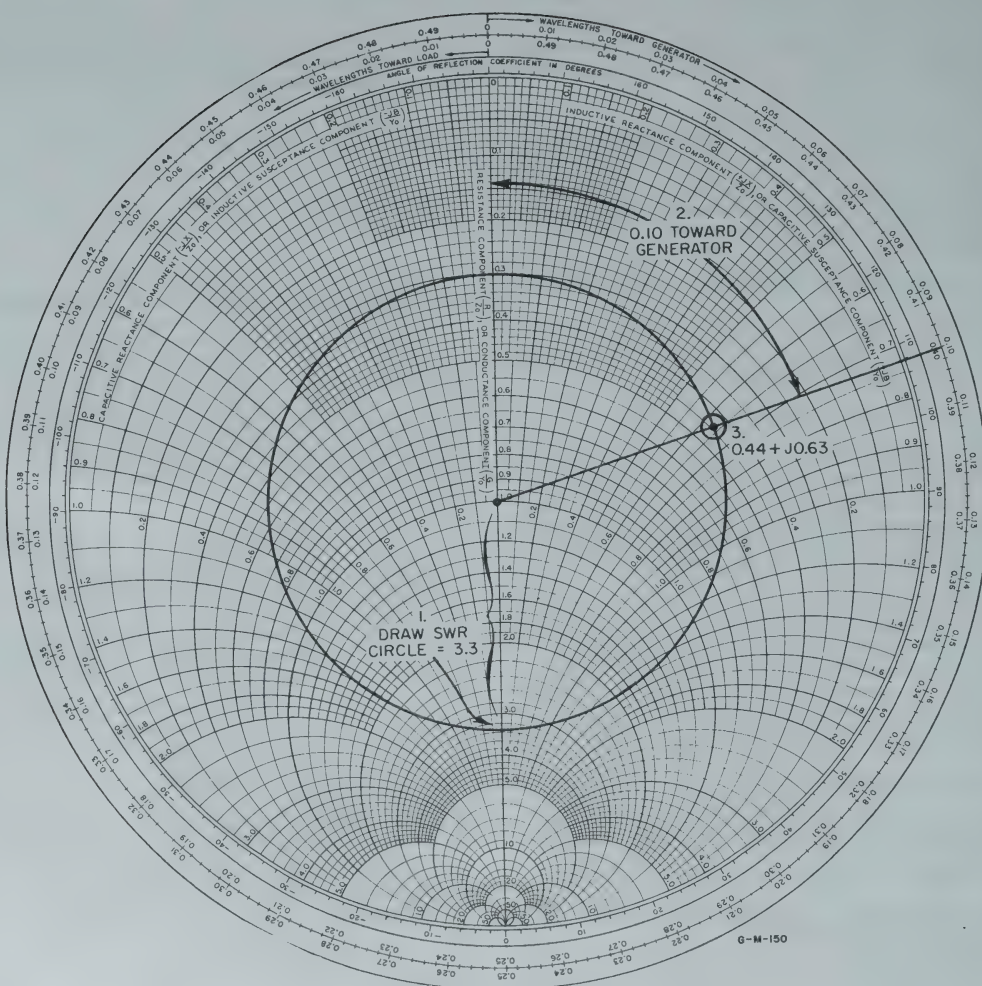


Figure 2-10. Smith Chart Showing Normalized Impedance

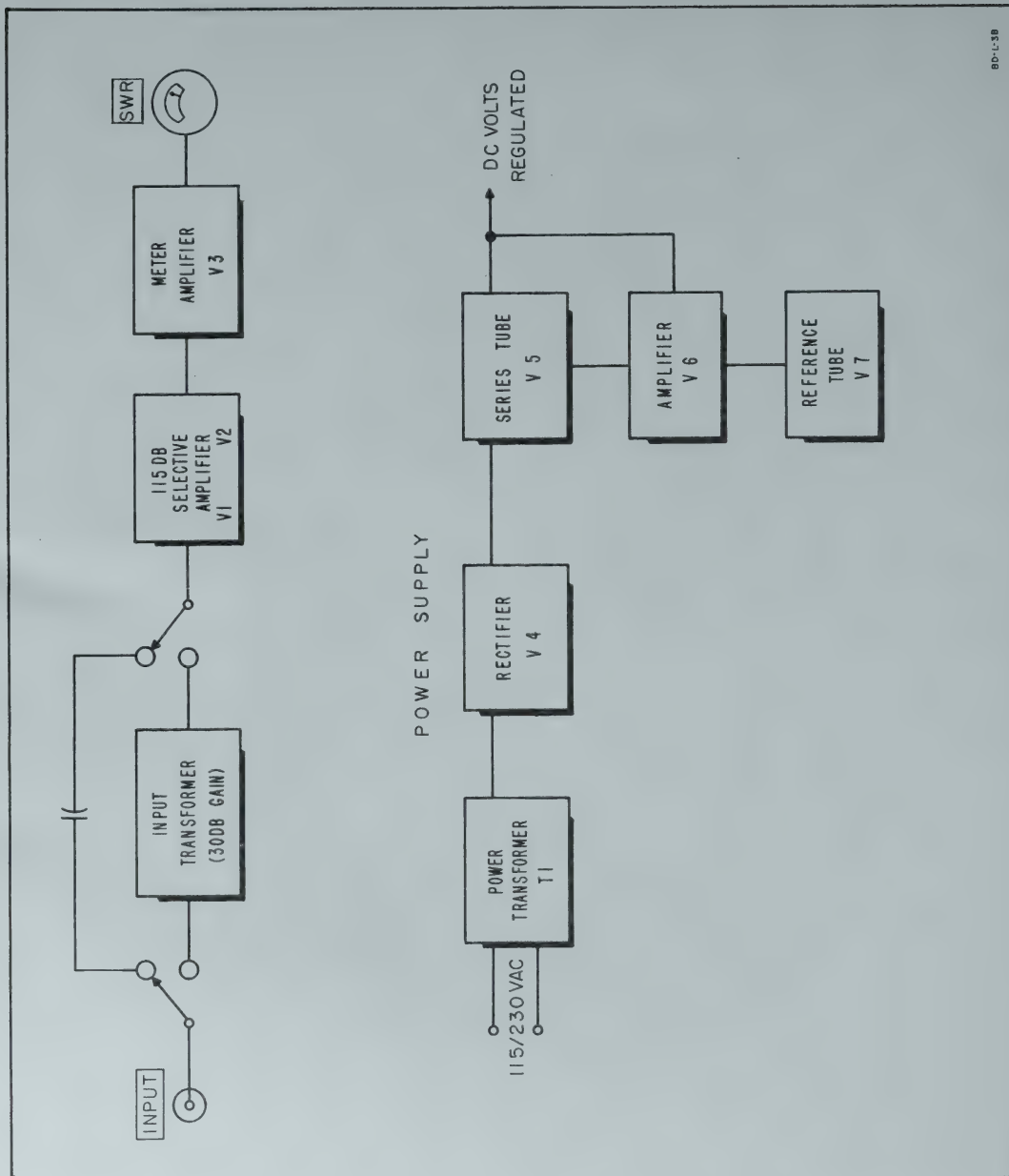


Figure 3-1. Model 415B Block Diagram

SECTION III

PRINCIPLES OF OPERATION

3-1 CIRCUIT DESCRIPTION

The Model 415B Standing Wave Indicator consists of a high-gain amplifier with very low noise level, a plug-in filter, an indicating meter and an electronic regulated power supply. All tubes of the instrument are shown in block diagram in Figure 3-1.

3-2 FREQUENCY SELECTIVE AMPLIFIER

The frequency selective amplifier consists of a step-up input transformer, T2, four resistance-coupled amplifier stages and a fourth stage drives a Fixed-frequency filter. The amplifier without the input transformer provides a total gain of 115-db gain, while T2 provides an additional 30 db.

The input circuit to an amplifier is arranged to match various external signal sources such as a crystal diode, barretter or a relatively high-impedance device (bridge circuit, etc.). When the input circuit is switched to XTAL-200K Ω the INPUT jack connects through the RANGE switch, S5, to the grid of the first amplifier stage. In the XTAL-200 Ω position, the INPUT jack connects to the primary of T2 which provides a reflected load of 200 ohms to any device connected to the INPUT jack.

In BOLO position the INPUT jack connects to the primary of the input transformer as above; except that the primary winding is now returned to R2 and R3 which provide dc operating bias to any 200 detector element connected to the INPUT. Diodes CR3 through CR6 maintain the voltage at the INPUT jack at a low level to reduce the transient current from C2 when a detector element is connected. The HIGH-LOW switch shunts the bias source with R1 so that two different values of bias (4.3 and 8.7 ma) may be used. The MONITOR jack is supplied so that an external milliammeter may be used to measure the bias current passing through the detector.

The RANGE switch, S5, consists of a three-section step attenuator which changes the gain of the amplifier in 20-db steps. However, to obtain square law meter calibration, the steps are calibrated 10 db on the front panel. The three sections of the attenuator are located in the grid circuits of the first three amplifier stages, V1A, B and V2A. The third section provides the first attenuation step, the second section the second attenuation step and the first section provides the remaining four attenuation steps. Selected precision resistors are used throughout the range switch. Because of the extremely high gain in this amplifier, the grounding of all parts in the first and second stages is very critical and specially indicated on the schematic diagram. The heavy lines indicate common negative tie points which in turn are together and connected to chassis only at J1.

The output level from the amplifier is controlled by a two-section potentiometer (GAIN, R22A and VERNIER, R22B.) in the grid circuit of the last amplifier stage. The potentiometers are connected in series, one providing approximately 25 db (12.5 db on the meter scale) of control for coarse adjustments, the other approximately 1.5 db (0.75 db on the meter scale) of control for fine adjustments.

Switch S4a between the second and third amplifier stages, when in the -5 db position, reduces the sensitivity of the amplifier to decrease the SWR meter indication by 5 db so that down-scale meter readings may be made upscale on the next lower range of the RANGE switch.

To make the amplifier frequency selective, the plate circuit of the last stage is loaded with parallel resonant circuit, Z1, having an effective Q between 20 and 30. The tuned circuit allows a 1000-cps signal to pass unattenuated, while the decreased impedance at off resonant frequencies attenuates these frequencies considerably. The effective bandwidth is approximately 40 cycles at the half-power points.

3-3 METER CIRCUIT

The 1000-cps signal from the selective amplifier is applied to a two-stage feedback amplifier which operates crystal rectifiers CR1, CR2 and the indicating meter M1. To assure linear operation, negative feedback is used around both the amplifier and the rectifier circuit. A 0.46-volt rms signal is required at the first grid of V3 to obtain a full scale meter indication. The signal from the second plate of V3 is fed to crystal diode CR2 which allows current to flow through R37 and the meter during the negative half of the signal cycle. During the positive half cycle the current returns through CR1 and R36.

Front panel selector S4, when set to the EXPAND position, applied a dc bucking voltage to the meter rectifiers so that a meter reading is forced off-scale, i.e., downward. The amplifier sensitivity must then be increased to obtain an upscale reading; which can then be read on the expanded meter scales.

3-4 POWER SUPPLY

The power supply consists of a power transformer with a single high-voltage winding feeding a full wave rectifier and electronic voltage regulator supplying dc to all the circuits of the standing wave indicator. The voltage regulator circuit maintains constant output voltage with wide changes in load current and line voltage.


V5, V6 and V7 constitute the voltage regulator circuit. V7 is a constant-voltage tube which provides the reference bias for V6. V5 operates as a series tube, or variable resistor, controlled by the voltage at the grid of V6. If the regulated B+ at the cathode of V5 tends to increase, the grid voltage for V6 increases causing V6 to draw more current. This lowers the plate voltage of V6 and therefore the grid voltage of V5 and results in greater plate resistance for V5. The greater plate resistance causes a greater voltage drop across V5, compensating for the increased voltage at its cathode and resulting in a substantially constant voltage output.

If the regulated B+ voltage tends to decrease, the reverse of the above action occurs, also tending to maintain the cathode voltage substantially constant. Ripple in the output voltage is coupled to the grid of V6 by capacitor C12. Variations in the dc voltage are coupled to the grid of V6 through the voltage divider R44, R45 and R46. The bias for V6 and the level of the output voltage from V5 are determined by the setting of R45.

The heaters of amplifier tubes V1, V2 and V3 are operated from a positive biased heater winding to reduce hum pickup from the heaters of these tubes. The bias voltage is obtained from a 10 volt point on the voltage divider stick R44, R46 and R48 in the power supply.

SECTION IV MAINTENANCE

4-1 INTRODUCTION

This section contains instructions for adjustment and repair of the  Model 415B Standing Wave Indicator. The information in this section is as follows:

- 4-2 Trouble Shooting the 415B
- 4-3 Replacing Tubes
- 4-4 Replacing Crystal Diodes
- 4-5 Range Switch Repairs
- 4-6 Equipment Required for Test and Adjustment
- 4-7 Test and Adjustment Procedure (General)
- 4-8 Set Meter Mechanical Zero
- 4-9 Adjust Regulated Power Supply
- 4-10 Check Monitor Jack
- 4-11 Check Sensitivity
- 4-12 Check Range Tracking
- 4-13 Check Noise Level
- 4-14 Calibrate Expanded Scale
- 4-15 Check -5DB Switch

4-2 TROUBLE SHOOTING THE 415B

The Model 415B is basically a high-gain, tuned amplifier with a "relative" indicating voltmeter. The instrument has few critical circuits. The maximum sensitivity may decrease as the tubes weaken with age but the accuracy will not be affected. Only adjustment of the power supply and/or recalibration of the EXPANDED scale is necessary after tube replacement.

The accuracy of the meter calibration is largely determined by crystal diodes CR1 and CR2. The mechanical tracking of the meter movement and the linearity of the amplifier affect meter calibration accuracy to a lesser degree. The amplifier linearity does not normally change.

Any unstable condition can usually be traced to the power supply. The power supply can be quickly checked by measuring the dc output voltage and by noting the noise level indication on the 415B meter.

An incorrect regulated voltage and/or a high residual noise level can be corrected by adjustment or by changing tubes. A high residual noise level that cannot be traced to the power supply can usually be corrected by replacing tube V1.

Individual stage gain measurements can be used to analyze an inoperative instrument. Gain can be checked by applying a small voltage (0.01 volt) from an audio oscillator to each stage in turn and measuring the stage output voltage. Set the audio oscillator to the same frequency as filter Z1 (usually 1000 cps). The approximate gain from each stage is as follows:

STAGE	DB GAIN (approx.)
Input Transformer	30
V1a	34
V1b	27.5
V2a	31
V2b	22
V3	***

***Approximately a 0.46 volt rms signal at the input of V3 will give a full scale meter deflection.

4-3 REPLACING TUBES

The tubes in the Model 415B can be replaced without making any adjustments except for those in the regulated power supply. The EXPANDED scale calibration should be checked after replacement of V3. After changing tubes in the power supply, the output voltage of the power supply should be checked and adjusted. Control R45 should be adjusted to set the dc voltage between the chassis and the cathode of the series regulator tube.

When replacing V1, select a tube that minimizes the noise indication and if possible the microphonics also.

4-4 REPLACING CRYSTAL DIODES

Use diodes with a high front-to-back resistance ratio of several hundred to one or better when replacing diodes CR1 and CR2. Adjustments are not necessary following replacement of CR1 and CR2 except that the calibration of the EXPANDED scale should be checked.

4-5 RANGE SWITCH REPAIRS

The precision resistors on the RANGE switch are selected and matched for accuracy during manufacture. Attempted replacement of individual resistors is usually not practical. Replacement of the entire switch assembly is recommended as a time-saving measure and guarantee of maintaining the original calibration accuracy.

If replacement of a single resistor is necessary, the resistor must be very carefully selected to maintain attenuator accuracy. Avoid excessive soldering heat or twisting or bending of these resistor leads during installation.

4-6 EQUIPMENT REQUIRED FOR TEST AND ADJUSTMENT

The following test equipment is used for testing and adjusting the Model 415B Standing Wave Indicator during manufacture. Any equivalent test instruments can also be used.

- An Φ Model 200CD Wide Range Oscillator
- An Φ Model 400D, 400H, or 400L AC Vacuum Tube Voltmeter.
- A pair of Φ Model 350B Attenuators.
- An Φ Model 410B Vacuum Tube Voltmeter.
- An adjustable line voltage source with meter.
- An 0-10 dc milliammeter with a known internal resistance and connected to a three-circuit phone plug. Connect the positive terminal of the meter to the "ring" of a 1/4 inch diameter "tip-ring-sleeve" phone plug and the negative terminal to the "tip".
- A BNC connector with a 1 watt composition resistor connected between the center contact and the outer shell. The resistor value plus the resistance of the 0-10 dc milliammeter must equal 200 ohms.

---A pair of Φ Model AC-16A banana plug to banana plug shielded cables and an Φ Model AC-16B banana plug to BNC shielded cable.

4-7 TEST AND ADJUSTMENT PROCEDURE (General)

The procedures that follow are listed in a sequence that is most easily followed when all of the procedures are to be completed. In many cases, only one or two of the procedures will be needed and they can be done without completing all the other tests.

A ten to fifteen minute warm-up and a check of power supply output voltage is always recommended before making any other tests or adjustments.

The specifications for your Φ Model 415B Standing Wave Indicator are given in the front of this manual. The following test procedure contains extra checks to help you analyze a particular instrument. These extra checks and the data they contain cannot be considered as specifications.

NOTE

The Model 415B is calibrated for use with square law detectors such as crystals and barretters. The output voltage of these detectors varies directly with input power. The 415B compensates for this characteristic by being calibrated to indicate a 1 db change on the meter for a 2 db change in input voltage. Thus, each 10 db step on the 415B range switch represents a twenty db change in input voltage.

DURING ADJUSTMENT THE 415B INPUT SIGNAL IS CONTROLLED BY AN EXTERNAL ATTENUATOR CALIBRATED IN DB. THE INDICATION ON THE 415B WILL CHANGE ONE DECIBEL FOR EACH TWO DECIBELS CHANGE IN THE EXTERNAL ATTENUATOR SETTING.

4-8 SET METER MECHANICAL ZERO

Turn the 415B ON long enough for the meter movement to reach the ambient temperature within the cabinet. Turn the instrument OFF and set the mechanical zero while the meter is still warm.

Rotate the meter mechanical zero adjusting screw clockwise until the meter pointer is traveling to the left toward 1.3 on the EXPANDED SWR scale and stop at 1.3. If you overshoot, continue rotating the adjustment screw clockwise and again approach from the high side of the scale. The adjustment screw should not be turned counter-clockwise during any part of this adjustment.

4-9 ADJUST REGULATED POWER SUPPLY

Connect the 410B VTVM between cathode (pin 3) of series regulator tube V5 and chassis ground. Adjust control R45 for a voltmeter reading of 245 volts dc with the line voltage set to 115 volts. As the line voltage is varied between 103 and 127 volts, the reading on the voltmeter will normally not change by more than $\pm 1\%$.

4-10 CHECK MONITOR JACK

Insert the phone plug from the 0-10 dc milliammeter into the MONITOR jack. Attach the BNC connector with resistor to the INPUT. The milliammeter connections and the resistor value are given in paragraph 4-6.

Set the INPUT SELECTOR switch to BOLO. The milliammeter will usually indicate 8.4 ± 0.4 milliamperes with the BOLO BIAS CURRENT switch in the HIGH position or 4.3 ± 0.3 milliamperes with the switch in the LOW position.

If the currents are incorrect, check resistors R1, R2, and R3 as well as the power supply output voltage.

4-11 CHECK SENSITIVITY

Connect your test equipment as shown in Figure 4-1. The ac vtvm should be connected to the output of the attenuator set.

NOTE

Several precautions must be used if you wish accurate results when using the Figure 4-1 test set-up. At least 20 db of attenuation should be inserted in the attenuator set at all times. The maximum attenuation inserted by either attenuator should not be over 80 db. The Model 415B chassis connection through the third wire in the NEMA type power cord should be disabled by using a three-prong to two-prong polarized adapter. The only ground connection to the 415B must be through the shielded cable from the attenuator set.

Rotate the Model 415B GAIN control fully clockwise and the RANGE switch to 0 DB. Set the input switch to XTAL 200 Ω and the METER SCALE switch to the NORMAL position.

Tune the audio oscillator to the Model 415B filter frequency as indicated by maximum deflection of the 415B meter. Adjust the audio oscillator output to obtain a full scale indication on the 415B. The indication on the ac vtvm should be 0.1 volt or less.

The basic sensitivity of the Model 415B can be obtained by dividing the meter indication by 1,000,000. Each position of the 415B range switch multiplies the sensitivity by 10 or by 1,000,000 when you switch directly from the 0 DB to the 60 DB switch position.

If the basic sensitivity is found to be low, try several replacement tubes for V1, V2, and/or V3.

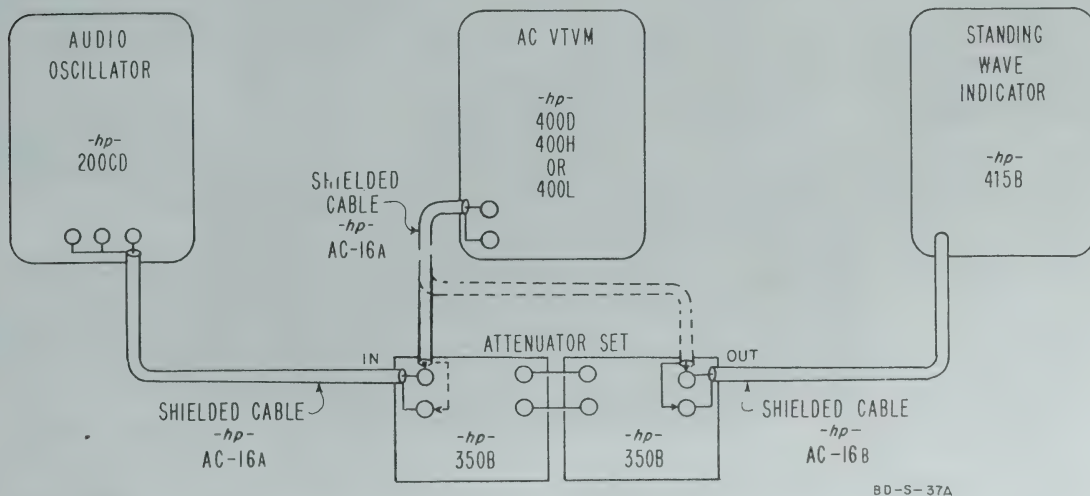


Figure 4-1. Instrument Connections for 415B Test and Adjustment

4-12 CHECK RANGE TRACKING

Connect the test equipment as shown in Figure 4-1. Connect the ac vtvm to the input of the attenuator set.

Rotate the Model 415B GAIN control fully clockwise and the RANGE switch to 0 DB. Set the input switch to XTAL 200 Ω and the METER SCALE switch to NORMAL.

Tune the audio oscillator to the 415B filter frequency as indicated by maximum deflection of the 415B meter. Adjust the audio oscillator output for a full scale indication of "0" on the db scale. Note the indication on the ac vtvm and adjust the output of the audio oscillator to keep this reading constant.

Add 20 db attenuation in the attenuator set and rotate the 415B RANGE switch to 10 DB. The 415B meter should again indicate 0 db \pm 0.1 db.

Repeat this procedure for each step of the 415B RANGE switch. The 415B meter should indicate within \pm 0.2 db of the full scale 0 db mark on all six ranges. Adjacent ranges should read within \pm 0.1 db of each other.

4-13 CHECK NOISE LEVEL

Connect the test equipment as shown in Figure 4-1. Connect the ac vtvm to the output of the attenuator set.

Rotate the Model 415B GAIN control fully clockwise and the RANGE switch to 0 DB. Set the input switch to XTAL 200 Ω and the METER SCALE switch to NORMAL.

Tune the audio oscillator to the 415B filter frequency as indicated by maximum deflection of the 415B meter. Adjust the audio oscillator output to obtain an indication of 0.03 volts on the ac vtvm. Note the indication on any convenient scale of the 415B. This indication will be used as a "reference".

Disconnect the ac vtvm and the audio oscillator. Set both 350B attenuators for 110 db attenuation. This is the only exception to the precaution given in the NOTE for Figure 4-1. Switch the 415B RANGE switch to 60 DB.

The indication on the 415B should be less than (to the left of) the "reference" indication noted above.

4-14 CALIBRATE EXPANDED SCALE

Connect the test equipment as shown in Figure 4-1. Connect the ac vtvm to the input of the attenuator set.

Rotate the Model 415B GAIN control fully clockwise and the RANGE switch to 0 DB. Set the input switch to XTAL 200 Ω and the METER SCALE switch to EXPAND.

Tune the audio oscillator to the 415B filter frequency as indicated by maximum deflection of the 415B meter. Check that the attenuator set is introducing at least 20 db of the attenuation and adjust the output of the audio oscillator to provide a full scale indication.

Attenuate the signal 4 db with the attenuator set. The 415B should now indicate 2 DB on the EXPANDED DB scale. If not, repeat the following procedure until a 4 db attenuation drops the meter indication from full scale to exactly the 2 db mark: ---Note the meter deviation from the 2 db mark and adjust R33 to get an equal error on the other side of the 2 db mark. Readjust attenuator set and signal for a full scale deflection, then attenuate signal 4 db. Repeat until no additional adjustment is necessary.

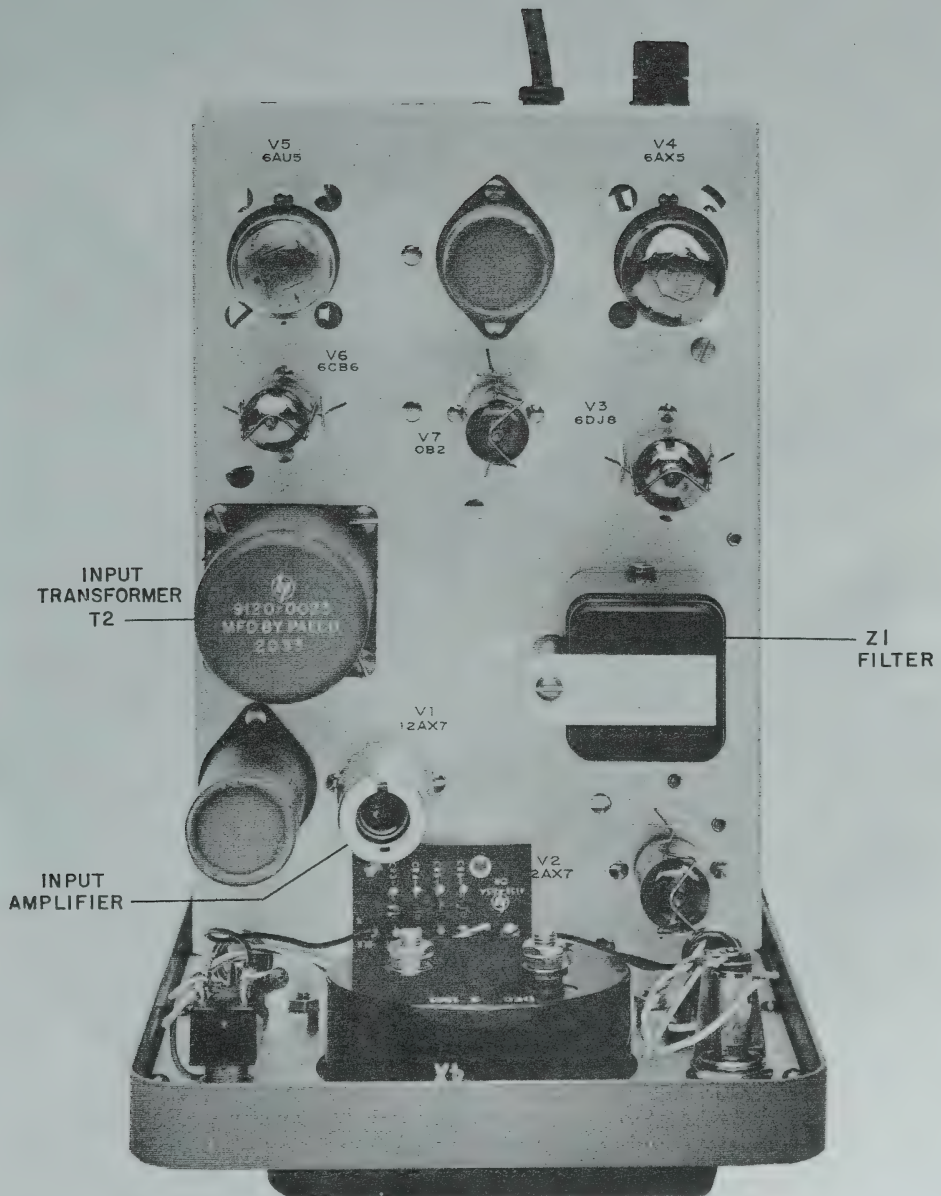
4-15 CHECK -5 DB SWITCH

Connect the test equipment as shown in Figure 4-1. Connect the ac vtvm to the input of the attenuator set.

Rotate the Model 415B GAIN control fully clockwise and the RANGE switch to any convenient position. Set the input switch to XTAL 200 Ω and the METER SCALE switch to NORMAL.

Tune the audio oscillator to the 415B filter frequency as indicated by maximum deflection of the 415B meter. Check that the attenuator set is introducing at least 30 db of attenuation and adjust the output of the audio oscillator to provide a "full scale" indication.

Increase the input signal to the Model 415B 10 db by decreasing the setting on the attenuator. Switch the meter scale switch to the -5 DB position. The 415B indication should remain at the "full scale" point.



MP-S-1071

Figure 4-2. Model 415B Top View

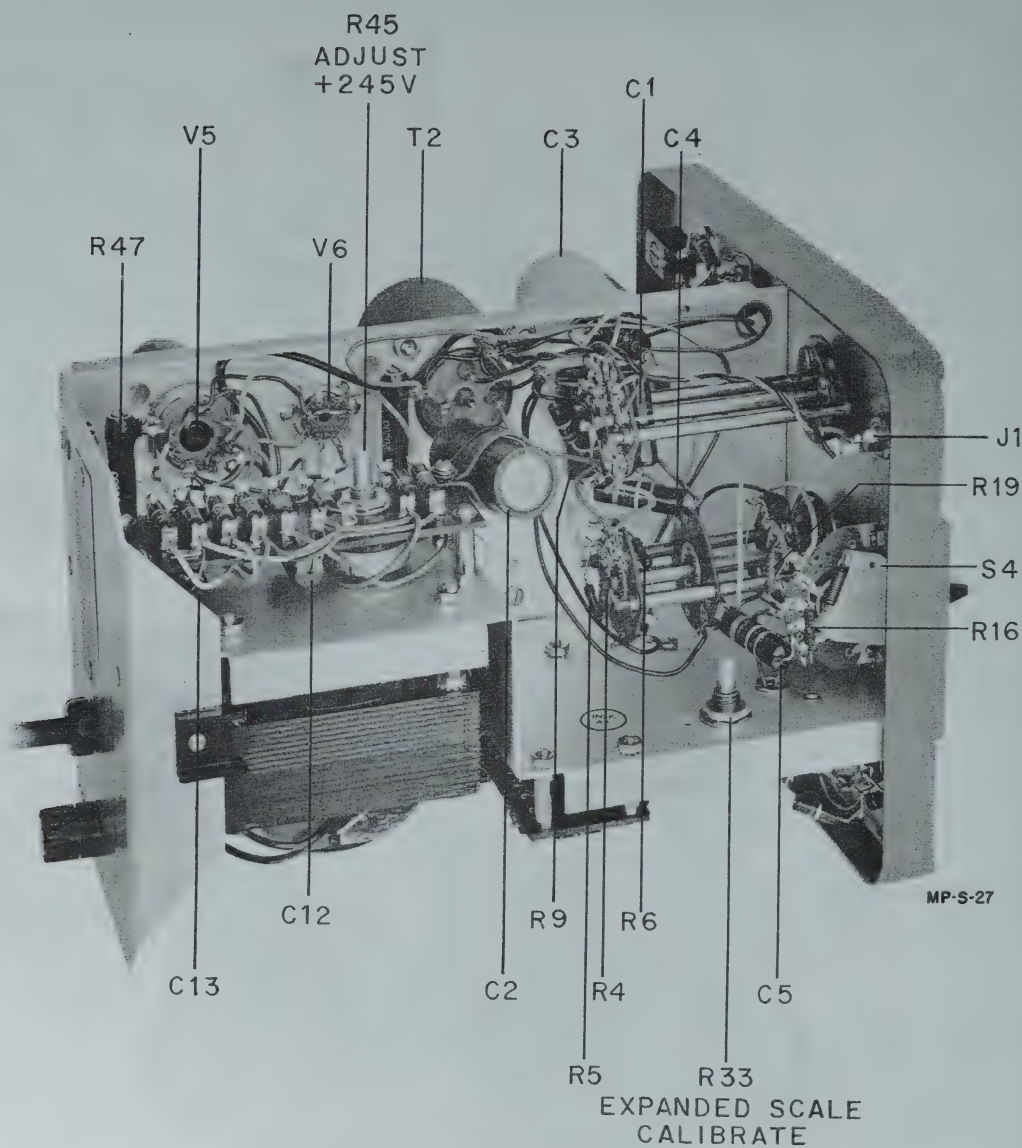
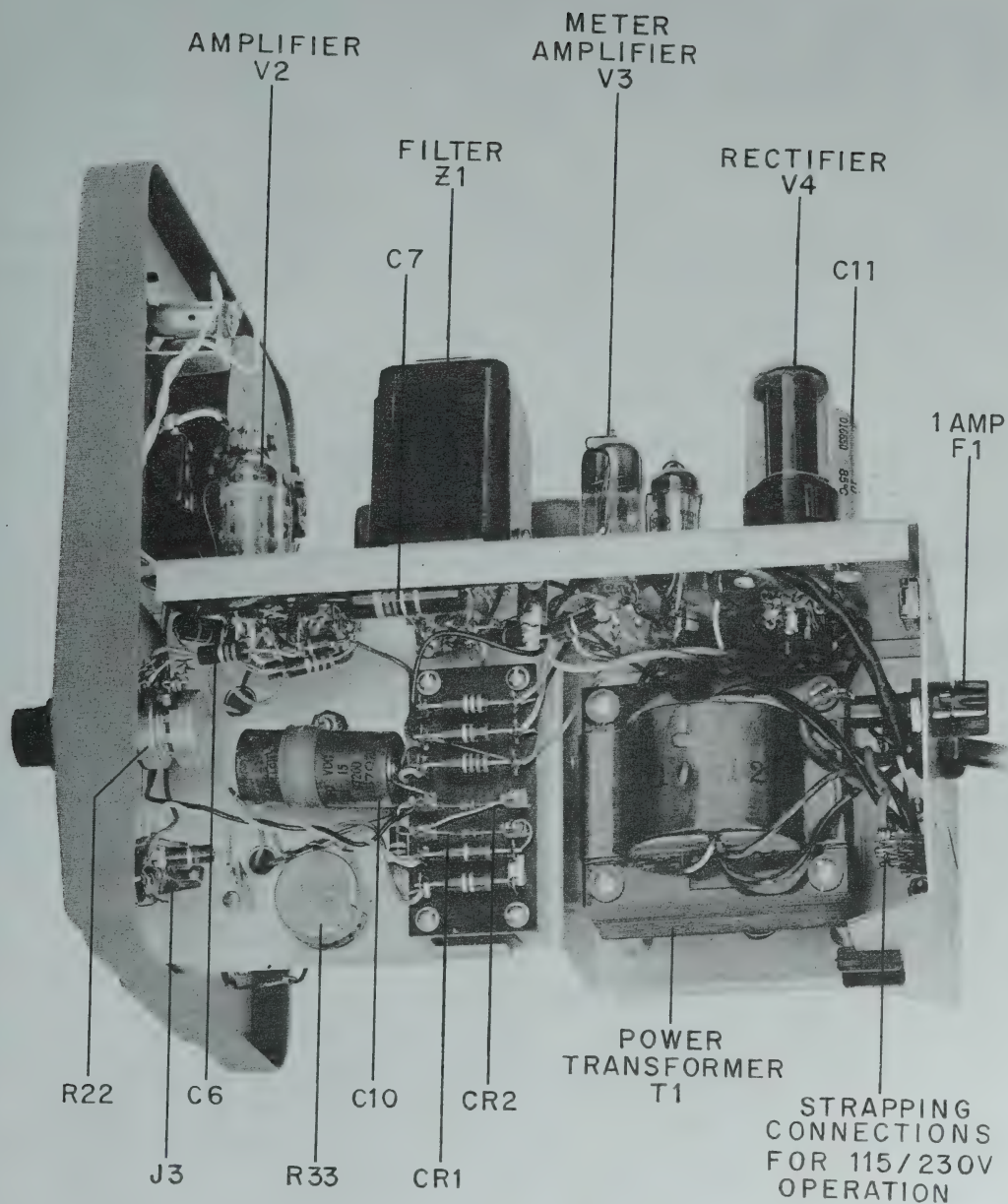


Figure 4-3. Model 415B Bottom View



MP-S-28

Figure 4-4. Model 415B Right Side

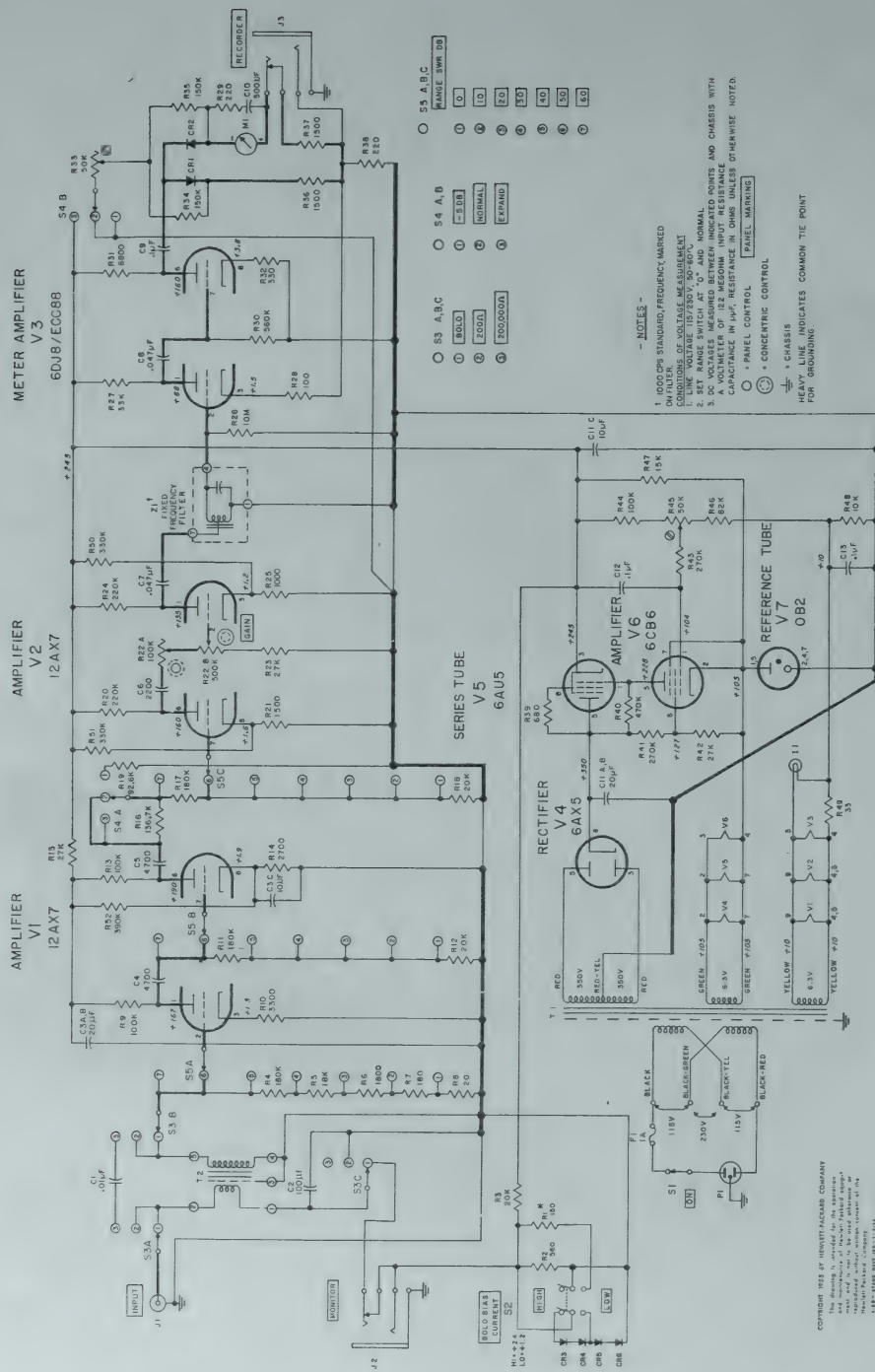


Figure 4-5. Model 415B Standing Wave Indicator

SECTION V

REPLACEABLE PARTS

5-1 INTRODUCTION

This section contains information for ordering replacement parts for the 415B Standing Wave Indicator.

5-2 TABLE OF REPLACEABLE PARTS

Table 5-1 lists replaceable parts in alpha-numerical order of their reference designators. At the end of the table are listed miscellaneous items such as knobs which have no assigned reference designators.

Detailed information on a part used more than once in the instrument is listed opposite the first reference designator applying to the part to appear in the table. Other reference designators applying to the same part reference the initial designator. The detailed information includes the following:

- 1) Full description of the part.
- 2) Manufacturer of the part in a five-digit code -- see list of manufacturers in appendix.
- 3) Total quantity used in the instrument (TQ column).
- 4) Recommended spare quantity for complete maintenance during one year of isolated service (RS column).

5-3 ORDERING INFORMATION


To order a replacement part, address order or inquiry either to your authorized Hewlett-Packard sales office or to

CUSTOMER SERVICE
Hewlett-Packard Company
395 Page Mill Road
Palo Alto, California

or, in western Europe, to

Hewlett-Packard S. A.
Rue du Vieux Billard No. 1
Geneva, Switzerland

Specify the following information on a part:

- 1) Model and serial number of the instrument. Be sure to include the three-digit serial prefix.
- 2)  stock number.
- 3) Circuit reference designator.
- 4) Description.

To order a part not listed in table 5-1, give a complete description of the part including its function and location in the circuit.

Table 5-1. Replaceable Parts (Sheet 1 of 5)


Ckt Ref.	Description	Mfr *	 Stock No.	TQ*	RS*		
C1	Capacitor: fixed, paper, .01 μ f $\pm 10\%$, 600 vdcw	56289	0160-0002	1	1		
C2	Capacitor: fixed, electrolytic, 100 μ f, 12 vdcw	56289	0180-0039	1	1		
C3A, B, C	Capacitor: fixed, electrolytic, 3 sections, 10 μ f -10% +50%, 450 vdcw	00656	0180-0016	2	1		
C4, 5	Capacitor: fixed, paper, .0047 μ f $\pm 10\%$, 600 vdcw	56289	0160-0010	2	1		
C6	Capacitor: fixed, paper, .0022 μ f $\pm 10\%$, 600 vdcw	56289	0160-0007	1	1		
C7, 8	Capacitor: fixed, paper, .047 μ f $\pm 10\%$, 600 vdcw	56289	0160-0005	2	1		

Table 5-1. Replaceable Parts (Sheet 2 of 5)

Ckt Ref.	Description	Mfr *	Ⓢ Stock No.	TQ*	RS*		
C9	Capacitor: fixed, paper, 0.1 μ f $\pm 10\%$, 400 vdcw	56289	0160-0013	3	1		
C10	Capacitor: fixed, elect., 500 μ f, 15 vdcw	37942	0180-0001	1	1		
C11A,B,C	Same as C3A,B,C						
C12,13	Same as C9						
CR1, 2	Diode, germanium	73293	1910-0011	2	2		
CR3,4,5,6	Diode, silicon	07933	1901-0025	4	4		
F1	Fuse, cartridge: 1 amp, slow blow for 115V operation	71400	2110-0007	1	10		
	Fuse, cartridge: 1/2 amp, slow blow for 230V operation	71400		1	0		
I1	Lamp, incandescent: 6-8V, .15 amp, #47	24455	2140-0009	1	1		
J1	Connector, female: 52 ohms impedance (cabinet model)	91737	1250-0083	1	1		
	Connector, female: BNC type (rack model)	91737	1250-0001	1	1		
J2, 3	Jack, telephone: for 3 conductor plug	82389	1251-0070	2	1		
M1	Meter	65092	1120-0044	1	1		
P1	Power cord	70903	8120-0050	1	1		
R1	Resistor: fixed, composition, 150 ohms $\pm 5\%$, 1 W	01121	0686-1515	1	1		
R2	Resistor: fixed, composition, 560 ohms $\pm 5\%$, 1 W Optimum value selected at factory Average value shown	01121	0689-5615	1	1		
R3	Resistor: fixed, wirewound, 20,000 ohms $\pm 10\%$, 10 W	35434	0816-0018	1	1		
R4	Resistor: fixed, deposited carbon, 180,000 ohms $\pm 1\%$, 1/2 W	19701	0727-0218	3	1		
R5	Resistor: fixed, deposited carbon, 18,000 ohms $\pm 1\%$, 1/2 W	19701	0727-0170	1	1		
R6	Resistor: fixed, deposited carbon, 1800 ohms $\pm 1\%$, 1/2 W	19701	0727-0112	1	1		
R7	Resistor: fixed, deposited carbon, 180 ohms $\pm 1\%$, 1/2 W	19701	0727-0050	1	1		

* See introduction to this section

Table 5-1. Replaceable Parts (Sheet 3 of 5)

Ckt Ref.	Description	Mfr *	Ⓢ Stock No.	TQ*	RS*		
R8	Resistor: fixed, deposited carbon, 20 ohms $\pm 1\%$, 1/2 W	19701	0727-0012	1	1		
R9	Resistor: fixed, deposited carbon, 100,000 ohms $\pm 1\%$, 1 W	19701	0730-0069	1	1		
R10	Resistor: fixed, composition, 3300 ohms $\pm 10\%$, 1 W	01121	0690-3321	1	1		
R11	Same as R4						
R12	Resistor: fixed, deposited carbon, 20,000 ohms $\pm 1\%$, 1/2 W	19701	0727-0173	2	1		
R13	Resistor: fixed, composition, 100,000 ohms $\pm 10\%$, 1 W	01121	0690-1041	2	1		
R14	Resistor: fixed, composition, 2700 ohms $\pm 10\%$, 1 W	01121	0690-2721	1	1		
R15	Resistor: fixed, composition, 27,000 ohms $\pm 10\%$, 1 W	01121	0690-2731	3	1		
R16	Resistor: fixed, deposited carbon, 136,700 ohms $\pm 1\%$, 1/2 W	19701	0727-0216	1	1		
R17	Same as R4						
R18	Same as R12						
R19	Resistor: fixed, deposited carbon, 92,600 ohms $\pm 1\%$, 1/2 W	19701	0727-0205	1	1		
R20	Resistor: fixed, composition, 220,000 ohms $\pm 10\%$, 1 W	01121	0690-2241	2	1		
R21	Resistor: fixed, composition, 1500 ohms $\pm 10\%$, 1 W	01121	0690-1521	3	1		
R22A, B	Resistor: variable, composition, dual section front sect., 500,000 ohms rear sect., 100,000 ohms	71590	2100-0071	1	1		
R23	Same as R15						
R24	Same as R20						
R25	Resistor: fixed, composition, 1000 ohms $\pm 10\%$, 1 W	01121	0690-1021	1	1		
R26	Resistor: fixed, composition, 10 megohms $\pm 10\%$, 1 W	01121	0690-1061	1	1		
R27	Resistor: fixed, composition, 33,000 ohms $\pm 10\%$, 1 W	01121	0690-3331	1	1		
R28	Resistor: fixed, composition, 100 ohms $\pm 10\%$, 1 W	01121	0690-1011	1	1		

* See introduction to this section

Table 5-1. Replaceable Parts (Sheet 4 of 5)

Ckt Ref.	Description	Mfr *	Ⓢ Stock No.	TQ*	RS*		
R29	Resistor: fixed, composition, 220 ohms $\pm 10\%$, 1 W	01121	0690-2211	2	1		
R30	Resistor: fixed, composition, 560,000 ohms $\pm 10\%$, 1 W	01121	0690-5641	1	1		
R31	Resistor: fixed, composition, 6800 ohms $\pm 10\%$, 1 W	01121	0690-6821	1	1		
R32	Resistor: fixed, composition, 330 ohms $\pm 10\%$, 1 W	01121	0690-3311	1	1		
R33	Resistor: variable, composition, linear taper, 50,000 ohms $\pm 20\%$	71590	2100-0013	1	1		
R34, 35	Resistor: fixed, composition, 150,000 ohms $\pm 10\%$, 1 W	01121	0690-1541	2	1		
R36, 37	Same as R21						
R38	Same as R29						
R39	Resistor: fixed, composition, 680 ohms $\pm 10\%$, 1 W	01121	0690-6811	1	1		
R40	Resistor: fixed, composition, 470,000 ohms $\pm 10\%$, 1 W	01121	0690-4741	1	1		
R41	Resistor: fixed, composition, 270,000 ohms $\pm 10\%$, 1 W	01121	0690-2741	2	1		
R42	Same as R15						
R43	Same as R41						
R44	Same as R13						
R45	Resistor: variable, composition, linear taper, 50,000 ohms $\pm 20\%$, 1/3 W	11237	2100-0084	1	1		
R46	Resistor: fixed, composition, 82,000 ohms $\pm 10\%$, 1 W	01121	0690-8231	1	1		
R47	Resistor: fixed, wirewound, 15,000 ohms $\pm 10\%$, 10 W	35434	0816-0013	1	1		
R48	Resistor: fixed, composition, 10,000 ohms $\pm 10\%$, 1 W	01121	0690-1031	1	1		
R49	Resistor: fixed, composition, 33 ohms $\pm 10\%$, 1 W	01121	0690-3301	1	1		
R50, 51	Resistor: fixed, composition, 330,000 ohms $\pm 10\%$, 1 W	01121	0690-3341	2	1		
R52	Resistor: fixed, composition, 390,000 ohms $\pm 10\%$, 1 W	01121	0690-3941	1	1		

* See introduction to this section

Table 5-1. Replaceable Parts (Sheet 5 of 5)

Ckt Ref.	Description	Mfr *	Ⓢ Stock No.	TQ*	RS*		
S1	Switch, toggle: SPST	04009	3101-0001	1	1		
S2	Switch, toggle: DPDT	04009	3101-0005	1	1		
S3A, B, C	Switch, rotary: 1 section, 3 positions	76854	3100-0114	1	1		
S4	Switch, lever: 3 positions, cabinet model, rack model	71590	3100-0113	1	1		
S5	Range Switch Assembly, includes C4, C5, R4 thru R8, R11, R12, R17, R18	28480	415B-19A	1	1		
T1	Transformer, power	98734	9100-0059	1	1		
T2	Transformer, input	98734	9120-0023	1	1		
V1, 2	Tube, electron: 12AX7	80131	1932-0030	2	2		
V3	Tube, electron: 6DJ8/ECC88	80131	1932-0022	1	1		
V4	Tube, electron: 6AX5	80131	1930-0014	1	1		
V5	Tube, electron: 6AU5	80131	1923-0020	1	1		
V6	Tube, electron: 6CB6	80131	1923-0028	1	1		
V7	Tube, electron: OB2	80131	1940-0007	1	1		
Z1	Filter Assembly: 1000-cycle	28480	415B-42A	1	1		
	Filter, special frequency: specify the particular frequency desired between 315 and 700 cps but avoid multiples of 60 cps by at least 15 cps.	28480	415B-42B				
	Filter, special frequency: specify the particular frequency desired between 700 and 2000 cps but avoid multiples of 60 cps by at least 15 cps.	28480	415B-42C				
	<u>MISCELLANEOUS</u>						
	Cable, external	28480	41A-16E	1	0		
	Fuseholder	75915	1400-0084	1	1		
	Knob: lever	28480	G-74AA	1	0		
	Knob: GAIN (3/4 inch)	28480	G-74A	1	0		
	Knob: GAIN (with arrow)	28480	G-74L	1	0		
	Knob: RANGE, BOLO. CRYSTAL	28480	G-74N	2	0		

*See introduction to this section

APPENDIX **CODE LIST OF MANUFACTURERS (Sheet 1 of 2)**

The following code numbers are from the Federal Supply Code for Manufacturers Cataloging Handbooks H4-1 (Name to Code) and H4-2 (Code to Name) and their latest supplements. The date of revision and the date of the supplements used appear at the bottom of each page. Alphabetical codes have been arbitrarily assigned to suppliers not appearing in the H4 handbooks.

CODE NO.	MANUFACTURER	ADDRESS	CODE NO.	MANUFACTURER	ADDRESS	CODE NO.	MANUFACTURER	ADDRESS
00334	Humidial Co.	Colton, Calif.	07137	Transistor Electronics Corp.	Minneapolis, Minn.	47904	Polaroid Corp.	Cambridge, Mass.
00335	Westrex Corp.	New York, N.Y.	07138	Westinghouse Electric Corp.	Electronic Tube Div.	48620	Precision Thermometer and Inst. Co.	Philadelphia, Pa.
00373	Garlock Packing Co., Electronic Products Div.	Camden, N.J.	07261	Avnet Corp.	Los Angeles, Calif.	49956	Raytheon Company	Lexington, Mass.
00656	Aerovox Corp.	New Bedford, Mass.	07263	Fairchild Semiconductor Corp.	Mountain View, Calif.	54294	Shallcross Mfg. Co.	Selma, N.C.
00779	Amp, Inc.	Harrisburg, Pa.	07910	Continental Device Corp.	Hawthorne, Calif.	55026	Simpson Electric Co.	Chicago, Ill.
00781	Aircraft Radio Corp.	Boonton, N.J.	07933	Rheem Semiconductor Corp.	Mountain View, Calif.	55933	Sonotone Corp.	Elmsford, N.Y.
00853	Sangamo Electric Company, Ordill Division (Capacitors)	Marion, Ill.	07980	Boonton Radio Corp.	Boonton, N.J.	55938	Sorenson & Co., Inc.	So. Norwalk, Conn.
00866	Goe Engineering Co.	Los Angeles, Calif.	08145	U.S. Engineering Co.	Los Angeles, Calif.	56137	Spaulding Fibre Co., Inc.	Tonawanda, N.Y.
00891	Carl E. Holmes Corp.	Los Angeles, Calif.	08358	Burgess Battery Co.	Niagara Falls, Ontario, Canada	56289	Sprague Electric Co.	North Adams, Mass.
01121	Allen Bradley Co.	Milwaukee, Wis.	08717	Sloan Company	Burbank, Calif.	59446	Telex, Inc.	St. Paul, Minn.
01255	Liton Industries, Inc.	Beverly Hills, Calif.	08718	Cannon Electric Co.	Phoenix Div.	61775	Union Switch and Signal, Div. of Westinghouse Air Brake Co.	Swissvale, Pa.
01281	Pacific Semiconductors, Inc.	Culver City, Calif.	08792	CBS Electronics Semiconductor Operations, Div. of C.B.S. Inc.	Lowell, Mass.	62119	Universal Electric Co.	Owosso, Mich.
01295	Texas Instruments, Inc., Transistor Products Div.	Dallas, Texas	09026	Babcock Relays, Inc.	Costa Mesa, Calif.	64959	Western Electric Co., Inc.	New York, N.Y.
01349	The Alliance Mfg. Co.	Alliance, Ohio	09134	Texas Capacitor Co.	Houston, Texas	65092	Weston Inst. Div. of Daystrom, Inc.	Newark, N.J.
01561	Chassi-Trak Corp.	Indianapolis, Ind.	09250	Electro Assemblies, Inc.	Chicago, Ill.	66346	Wollensak Optical Co.	Rochester, N.Y.
01589	Pacific Relays, Inc.	Van Nuys, Calif.	09569	Mallory Battery Co. of Canada Ltd.	Toronto, Ontario, Canada	70276	Allen Mfg. Co.	Hartford, Conn.
01930	Amerock Corp.	Rockford, Ill.	10214	General Transistor Western Corp.	Los Angeles, Calif.	70309	Allied Control Co., Inc.	New York, N.Y.
01961	Pulse Engineering Co.	Saugerties, N.Y.	10411	Ti-Tal, Inc.	Berkeley, Calif.	70485	Atlantic India Rubber Works, Inc.	Chicago, Ill.
02114	Ferroxcube Corp. of America	Palo Alto, Calif.	10646	Carborundum Co.	Niagara Falls, N.Y.	70563	Amperite Co., Inc.	New York, N.Y.
02286	Cole Mfg. Co.	Chicago, Ill.	11236	CTS of Berne, Inc.	Berne, Ind.	70903	Belden Mfg. Co.	Chicago, Ill.
02660	Amphenol-Borg Electronics Corp.	Somerville, N.J.	11237	Chicago Telephone of California, Inc.	So. Pasadena, Calif.	70998	Bird Electronic Corp.	Cleveland, Ohio
02735	Radio Corp. of America Semiconductor and Materials Div.	Somerville, N.J.	11312	Microwave Electronics Corp.	Palo Alto, Calif.	71002	Birnbach Radio Co.	New York, N.Y.
02771	Vocaline Co. of America, Inc.	Old Saybrook, Conn.	11711	General Instrument Corporation Semiconductor Division	Newark, N.J.	71041	Boston Gear Works Div. of Murray Co. of Texas	Quincy, Mass.
02777	Hopkins Engineering Co.	San Fernando, Calif.	11717	Imperial Electronics, Inc.	Buena Park, Calif.	71218	Bud Radio Inc.	Cleveland, Ohio
03508	G.E. Semiconductor Products Dept.	Syracuse, N.Y.	11870	Melabs, Inc.	Palo Alto, Calif.	71286	Camloc Fastener Corp.	Paramus, N.J.
03705	Apex Machine & Tool Co.	Dayton, Ohio	12697	Claroat Mfg. Co.	Dover, N.H.	71313	Allen D. Cardwell Electronic Prod. Corp.	Plainville, Conn.
03797	Eldema Corp.	El Monte, Calif.	14655	Cornell Dubilier Elec. Corp.	So. Plainfield, N.J.	71400	Bussmann Fuse Div. of McGraw-Edison Co.	St. Louis, Mo.
03877	Transitron Electronic Corp.	Wakefield, Mass.	15909	The Daven Co.	Livingston, N.J.	71450	CTS Corp.	Elkhart, Ind.
03888	Pyrofilm Resistor Co.	Morristown, N.J.	16688	De Jur-Amsco Corporation	Long Island City 1, N.Y.	71468	Cannon Electric Co.	Los Angeles, Calif.
03954	Air Marine Motors, Inc.	Los Angeles, Calif.	16758	Delco Radio Div. of G. M. Corp.	Kokomo, Ind.	71471	Cinema Engineering Co.	Burbank, Calif.
04009	Arrow, Hart and Hegeman Elect. Co.	Hartford, Conn.	18873	E. I. DuPont and Co., Inc.	Wilmington, Del.	71482	C. P. Clare & Co.	Chicago, Ill.
04062	Elmenco Products Co.	New York, N.Y.	19315	Eclipse Pioneer, Div. of Bendix Aviation Corp.	Teterboro, N.J.	71528	Standard-Thomson Corp., Clifford Mfg. Co. Div.	Waltham, Mass.
04222	Hi-Q Division of Aerovox	Myrtle Beach, S.C.	19500	Thomas A. Edison Industries, Div. of McGraw-Edison Co.	West Orange, N.J.	71590	Centralab Div. of Globe Union Inc.	Milwaukee, Wis.
04298	Elgin National Watch Co., Electronics Division	Burbank, Calif.	19701	Electra Manufacturing Co.	Kansas City, Mo.	71700	The Cornish Wire Co.	New York, N.Y.
04404	Dymec Division of Hewlett-Packard Co.	Palo Alto, Calif.	20183	Electronic Tube Corp.	Philadelphia, Pa.	71744	Chicago Miniature Lamp Works	Chicago, Ill.
04651	Sylvania Electric Prods., Inc. Electronic Tube Div.	Mountain View, Calif.	21520	Fanstel Metallurgical Corp.	No. Chicago, Ill.	71753	A. O. Smith Corp., Crow Div.	West Orange, N.J.
04713	Motorola, Inc., Semiconductor Prod. Div.	Phoenix, Arizona	21335	The Fafnir Bearing Co.	New Britain, Conn.	71785	Cinch Mfg. Corp.	Chicago, Ill.
04732	Filtrol Co., Inc., Western Division	Culver City, Calif.	21964	Fed. Telephone and Radio Corp.	Clifton, N.J.	71984	Dow Corning Corp.	Midland, Mich.
04773	Automatic Electric Co.	Northlake, Ill.	24446	General Electric Co.	Schenectady, N.Y.	72136	Electro Motive Mfg. Co., Inc.	Willmantic, Conn.
04870	P. M. Motor Co.	Chicago, Ill.	24455	G.E. Lamp Division	Nela Park, Cleveland, Ohio	72354	John E. Fast & Co.	Chicago, Ill.
05006	Twentieth Century Plastics, Inc.	Los Angeles, Calif.	24655	General Radio Co.	West Concord, Mass.	72619	Dialight Corp.	Brooklyn, N.Y.
05277	Westinghouse Electric Corp., Semi-Conductor Dept.	Youngwood, Pa.	26462	Grobet File Co. of America, Inc.	Carlstadt, N.J.	72656	General Ceramics Corp.	Kearsey, N.J.
05347	Ultrinox, Inc.	San Mateo, Calif.	26992	Hamilton Watch Co.	Lancaster, Pa.	72758	Girard-Hopkins	Oakland, Calif.
05593	Illumitronic Engineering Co.	Sunnyvale, Calif.	28480	Hewlett-Packard Co.	Palo Alto, Calif.	72765	Drake Mfg. Co.	Chicago, Ill.
05624	Barber Colman Co.	Rockford, Ill.	33173	G.E. Receiving Tube Dept.	Owensboro, Ky.	72825	Hugh H. Eby Inc.	Philadelphia, Pa.
05729	Metropolitan Telecommunications Corp., Metro Cap. Div.	Brooklyn, N.Y.	35434	Lectrohm Inc.	Chicago, Ill.	72928	Gudeman Co.	Chicago, Ill.
05783	Stewart Engineering Co.	Santa Cruz, Calif.	37942	P. R. Mallory & Co., Inc.	Indianapolis, Ind.	72982	Erie Resistor Corp.	Erie, Pa.
06004	The Bassick Co.	Bridgeport, Conn.	39543	Mechanical Industries Prod. Co.	Akron, Ohio	73061	Hansen Mfg. Co., Inc.	Princeton, Ind.
06555	Beebe Electrical Instrument Co., Inc.	Penacook, N.H.	40920	Miniature Precision Bearings, Inc.	Keene, N.H.	73138	Helipot Div. of Beckman Instruments, Inc.	Fullerton, Calif.
06812	Torrington Mfg. Co., West Div.	Van Nuys, Calif.	42190	Muter Co.	Chicago, Ill.	73293	Hughes Products Division of Hughes Aircraft Co.	Newport Beach, Calif.
07115	Corning Glass Works Electronic Components Dept.	Bradford, Pa.	43990	C. A. Norgren Co.	Englewood, Colo.	73445	Amperes Electronic Co., Div. of North American Phillips Co., Inc.	Hicksville, N.Y.
07126	Digitran Co.	Pasadena, Calif.	44655	Ohmite Mfg. Co.	Skokie, Ill.	73506	Bradley Semiconductor Corp.	Hamden, Conn.

From: F.S.C. Handbook Supplements
H4-1 Dated December 1961
H4-2 Dated December 1961

APPENDIX **CODE LIST OF MANUFACTURERS (Sheet 2 of 2)**

CODE NO.	MANUFACTURER	ADDRESS	CODE NO.	MANUFACTURER	ADDRESS	CODE NO.	MANUFACTURER	ADDRESS
74868	R.F. Products Division of Amphenol-Borg Electronics Corp.	Danbury, Conn.	82893	Vector Electronic Co.	Glendale, Calif.	95354	Methode Mfg. Co.	Chicago, Ill.
74970	E. F. Johnson Co.	Waseca, Minn.	83053	Western Washer Mfr. Co.	Los Angeles, Calif.	95987	Wegesser Co.	Chicago, Ill.
75042	International Resistance Co.	Philadelphia, Pa.	83058	Carr Fastener Co.	Cambridge, Mass.	96067	Huggins Laboratories	Sunnyvale, Calif.
75173	Jones, Howard B., Division of Cinch Mfg. Corp.	Chicago, Ill.	83086	New Hampshire Ball Bearing, Inc.	Peterborough, N.H.	96095	Hi-Q Division of Aerovox	Olean, N.Y.
75378	James Knights Co.	Sandwich, Ill.	83125	Pyramid Electric Co.	Darlington, S.C.	96256	Thordarson-Meissner Div. of Maguire Industries, Inc.	Mt. Carmel, Ill.
75382	Kulka Electric Corporation	Mt. Vernon, N.Y.	83148	Electro Cords Co.	Los Angeles, Calif.	96296	Solar Manufacturing Co.	Los Angeles, Calif.
75818	Lenz Electric Mfg. Co.	Chicago, Ill.	83186	Victory Engineering Corp.	Union, N.J.	96330	Carlton Screw Co.	Chicago, Ill.
75915	Littelfuse Inc.	Des Plaines, Ill.	83298	Bendix Corp., Red Bank Div.	Red Bank, N.J.	96341	Microwave Associates, Inc.	Burlington, Mass.
76005	Lord Mfg. Co.	Erie, Pa.	83330	Smith, Herman H., Inc.	Brooklyn, N.Y.	96501	Excel Transformer Co.	Oakland, Calif.
76210	C. W. Marwedel	San Francisco, Calif.	83501	Gavitt Wire and Cable Co., Div. of Amerace Corp.	Brookfield, Mass.	97464	Industrial Retaining Ring Co.	Irvington, N.J.
76433	Micamold Electronic Mfg. Corp.	Brooklyn, N.Y.	83594	Burroughs Corp., Electronic Tube Div.	Plainfield, N.J.	97539	Automatic and Precision Mfg. Co.	Yonkers, N.Y.
76487	James Millen Mfg. Co., Inc.	Malden, Mass.	83777	Model Eng. and Mfg., Inc.	Huntington, Ind.	97946	CBS Electronics, Div. of C.B.S., Inc.	Danvers, Mass.
76493	J. W. Miller Co.	Los Angeles, Calif.	83821	Loyd Scruggs Co.	Festus, Mo.	98141	Axel Brothers Inc.	Jamaica, N.Y.
76530	Monadnock Mills	San Leandro, Calif.	84171	Arco Electronics, Inc.	New York, N.Y.	98220	Francis L. Mosley	Pasadena, Calif.
76545	Mueller Electric Co.	Cleveland, Ohio	84396	A. J. Glesener Co., Inc.	San Francisco, Calif.	98278	Microdot, Inc.	So. Pasadena, Calif.
76854	Oak Manufacturing Co.	Chicago, Ill.	84411	Good All Electric Mfg. Co.	Ogallala, Neb.	98291	Sealectro Corp.	Mamaroneck, N.Y.
77068	Bendix Pacific Division of Bendix Corp.	No. Hollywood, Calif.	84970	Sarkes Tarzian, Inc.	Bloomington, Ind.	98405	Carad Corp.	Redwood City, Calif.
77221	Phaoston Instrument and Electronic Co.	South Pasadena, Calif.	85454	Bonfont Molding Company	Boonton, N.J.	98734	Palo Alto Engineering Co., Inc.	Palo Alto, Calif.
77342	Potter and Brumfield, Div. of American Machine and Foundry	Princeton, Ind.	85474	R. M. Bracamonte & Co.	San Francisco, Calif.	98821	North Hills Electric Co.	Mineola, N.Y.
77630	Radio Condenser Co.	Camden, N.J.	85660	Koiled Kords, Inc.	New Haven, Conn.	98925	Clevite Transistor Prod. Div. of Clevite Corp.	Waltham, Mass.
77638	Radio Receptor Co., Inc.	Brooklyn, N.Y.	85911	Seamless Rubber Co.	Chicago, Ill.	98978	International Electronic Research Corp.	Burbank, Calif.
77764	Resistance Products Co.	Harrisburg, Pa.	86197	Clifton Precision Products	Clifton Heights, Pa.	99109	Columbia Technical Corp.	New York, N.Y.
78189	Shakeproof Division of Illinois Tool Works	Elgin, Ill.	86684	Radio Corp. of America, RCA Electron Tube Div.	Harrison, N.J.	99313	Varian Associates	Palo Alto, Calif.
78283	Signal Indicator Corp.	New York, N.Y.	87216	Philco Corp. (Lansdale Division)	Lansdale, Pa.	99515	Marshall Industries, Electron Products Division	Pasadena, Calif.
78471	Tilley Mfg. Co.	San Francisco, Calif.	87473	Western Fibrous Glass Products Co.	San Francisco, Calif.	99707	Control Switch Division, Controls Co. of America	El Segundo, Calif.
78488	Stackpole Carbon Co.	St. Marys, Pa.	88140	Cutler-Hammer, Inc.	Lincoln, Ill.	99800	Delevan Electronics Corp.	East Aurora, N.Y.
78553	Tinnerman Products, Inc.	Cleveland, Ohio	88220	Gould-National Batteries, Inc.	St. Paul, Minn.	99848	Wilco Corporation	Indianapolis, Ind.
78790	Timmer Engineers	Pasadena, Calif.	89473	General Electric Distributing Corp.	Schenectady, N.Y.	99934	Renbrandt, Inc.	Boston, Mass.
78947	Ucinite Co.	Newtonville, Mass.	89636	Carter Parts Div. of Economy Baler Co.	Chicago, Ill.	99942	Hoffman Semiconductor Div. of Hoffman Electronics Corp.	Evanston, Ill.
79142	Veeder Root, Inc.	Hartford, Conn.	89665	United Transformer Co.	Chicago, Ill.	99957	Technology Instrument Corp. of Calif.	Newbury Park, Calif.
79251	Wenco Mfg. Co.	Chicago, Ill.	90179	U.S. Rubber Co., Mechanical Goods Div.	Passaic, N.J.			
79727	Continental-Wirt Electronics Corp.	Philadelphia, Pa.	90970	Bearing Engineering Co.	San Francisco, Calif.			
79963	Zierick Mfg. Corp.	New Rochelle, N.Y.	91260	Connor Spring Mfg. Co.	San Francisco, Calif.			
80031	Mepco Division of Sessions Clock Co.	Morristown, N.J.	91418	Radio Materials Co.	Chicago, Ill.			
80120	Schlitz Alloy Products	Elizabeth, N.J.	91506	Augar Brothers, Inc.	Attleboro, Mass.			
80130	Times Facsimile Corp.	New York, N.Y.	91637	Dale Electronics, Inc.	Columbus, Nebr.			
80131	Electronic Industries Association Any brand tube meeting EIA standards	Washington, D.C.	91662	Elco Corp.	Philadelphia, Pa.			
80207	Unimax Switch, Div. of W. L. Maxson Corp.	Wallingford, Conn.	91737	Gremar Mfg. Co., Inc.	Wakefield, Mass.			
80248	Oxford Electric Corp.	Chicago, Ill.	91827	K F Development Co.	Redwood City, Calif.			
80294	Burns Laboratories, Inc.	Riverside, Calif.	91921	Minneapolis-Honeywell Regulator Co., Micro-Switch Division	Freeport, Ill.			
80411	Acro Div. of Robertshaw Fulton Controls Co.	Columbus 16, Ohio	92196	Universal Metal Products, Inc.	Bassett Puento, Calif.			
80486	All Star Products Inc.	Defiance, Ohio	93332	Sylvania Electric Prod. Inc., Semiconductor Div.	Woburn, Mass.			
80583	Hammerlund Co., Inc.	New York, N.Y.	93369	Robbins and Myers, Inc.	New York, N.Y.			
80640	Stevens, Arnold, Co., Inc.	Boston, Mass.	93410	Stevens Mfg. Co., Inc.	Mansfield, Ohio			
81030	International Instruments, Inc.	New Haven, Conn.	93983	Insuline-Van Norman Ind., Inc., Electronic Division	Manchester, N.H.			
81415	Wilkor Products, Inc.	Cleveland, Ohio	94144	Raytheon Mfg. Co., Industrial Components Div., Receiving Tube Operation	Quincy, Mass.			
81453	Raytheon Mfg. Co., Industrial Components Div., Industr. Tube Operations	Newton, Mass.	94145	Raytheon Mfg. Co., Semiconductor Div., California Street Plant	Newton, Mass.			
81483	International Rectifier Corp.	El Segundo, Calif.	94148	Scientific Radio Products, Inc.	Loveland, Colo.			
81860	Barry Controls, Inc.	Watertown, Mass.	94154	Tung-Sol Electric, Inc.	Newark, N.J.			
82042	Carter Parts Co.	Skokie, Ill.	94197	Curtiss-Wright Corp., Electronics Div.	East Paterson, N.J.			
82142	Jeffers Electronics Division of Speer Carbon Co.	Du Bois, Pa.	94310	Tru Ohm Prod. Div. of Model Engineering and Mfg. Co.	Chicago, Ill.			
82170	Allen B. DuMont Labs., Inc.	Clifton, N.J.	94682	Worcester Pressed Aluminum Corp.	Worcester, Mass.			
82209	Maguire Industries, Inc.	Greenwich, Conn.	95236	Allies Products Corp.	Miami, Fla.			
82219	Sylvania Electric Prod. Inc., Electronic Tube Div.	Emporium, Pa.	95238	Continental Connector Corp.	Woodside, N.Y.			
82376	Astron Co.	East Newark, N.J.	95263	Leecraft Mfg. Co., Inc.	New York, N.Y.			
82389	Switchcraft, Inc.	Chicago, Ill.	95264	Lenco Electronics, Inc.	Burbank, Calif.			
82647	Metals and Controls, Inc., Texas Instruments, Inc., Spencer Prods.	Attleboro, Mass.	95265	National Coil Co.	Sheridan, Wyo.			
82866	Research Products Corp.	Madison, Wis.	95275	Vitramon, Inc.	Bridgeport, Conn.			
82877	Rotron Manufacturing Co., Inc.	Woodstock, N.Y.						

THE FOLLOWING H-P VENDORS HAVE NO NUMBER ASSIGNED IN THE LATEST SUPPLEMENT TO THE FEDERAL SUPPLY CODE FOR MANUFACTURERS HANDBOOK.

0000 F	Malco Tool and Die	Los Angeles, Calif.
0000 I	Telefunken (c/o American Elite)	New York, N.Y.
0000 L	Winchester Electronics, Inc.	Santa Monica, Calif.
0000 M	Western Coil Div. of Automatic Ind., Inc.	Redwood City, Calif.
0000 N	Nahm-Bros. Spring Co.	San Leandro, Calif.
0000 P	Ty-Car Mfg. Co., Inc.	Holliston, Mass.
0000 T	Texas Instruments, Inc., Metals and Controls Div.	Versailles, Ky.
0000 U	Tower Mfg. Corp.	Providence, R.I.
0000 W	Webster Electronics Co. Inc.	New York, N.Y.
0000 X	Spruce Pine Mica Co.	Spruce Pine, N.C.
0000 Y	Midland Mfg. Co., Inc.	Kansas City, Kans.
0000 Z	Willow Leather Products Corp.	Newark, N.J.
000 A A	British Radio Electronics Ltd.	Washington, D.C.
000 B B	Precision Instrument Components Co.	Van Nuys, Calif.
000 C C	Computer Diode Corp.	Lodi, N.J.
000 E E	A. Williams Manufacturing Co.	San Jose, Calif.
000 F F	Garmichael Corrugated Specialties	Richmond, Calif.
000 G G	Goshen Die Cutting Service	Goshen, Ind.
000 H H	Rubbercraft Corp.	Torrance, Calif.
000 I I	Birch Corporation, Industrial Division	Monterey Park, Calif.

From: F.S.C. Handbook Supplements
H4-1 Dated December 1961
H4-2 Dated December 1961

00015-21
Revised: 7 February 1962

9 August 65-4

-hp- MODEL 415B
STANDING WAVE INDICATOR
Serials Below 213-11683

NOISE REDUCTION

To reduce noise in the input stage of -hp- Model 415B Standing Wave Indicators, serials below 213-11683, change R10 to a resistor, fixed metal film 3.32K ohms, $\pm 1\%$, 1/8 watt, - hp- Part Number 0757-0433.

The parts list in the operating and service manual should be changed to show the new part.

F

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OPERATING AND SERVICE MANUAL

MODEL 415B

SERIALS PREFIXED: 213-

STANDING WAVE INDICATOR

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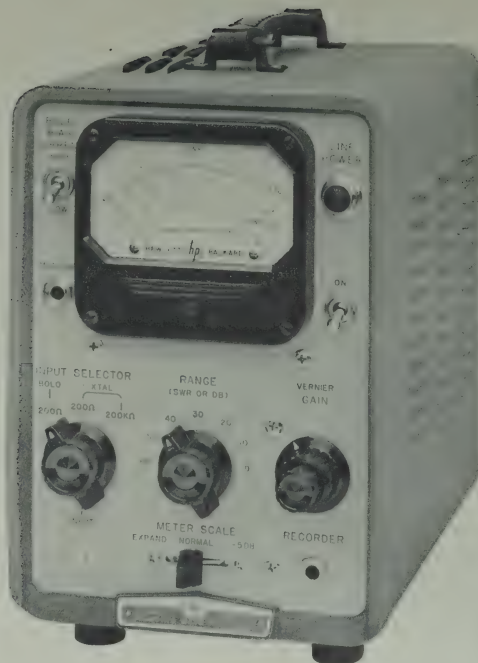


Figure 1-1. Model 415B Standing Wave Indicator

Table 1-1. Specifications

<p>Frequency: 1000 cps $\pm 2\%$. Other frequencies 315 to 2020 cps available on special order. Should not be harmonically related to power line frequency.</p> <p>Sensitivity: 0.1 μvolt at a 200-ohm level for full scale deflection.</p> <p>Noise Level: Less than 0.03 μvolt ref. to input operated from a 200-ohm resistor at room temperature.</p> <p>Amplifier Q: 30 (nominal)</p> <p>Calibration: Square law. Meter indicates swr, db.</p> <p>Range: 70 db. Input attenuator provides 60 db in 10 db steps. Accuracy ± 0.1 db per 10 db step. Maximum cumulative error ± 0.2 db.</p> <p>Scale Selector: "Normal", "Expand", and "-5 db".</p>	<p>Meter Scales: SWR 1-4, swr 3-10, expanded swr 1-1.3, db 0-10, expanded db 0-2.</p> <p>Gain Control: Adjusts to convenient reference level. Range at least 10 db.</p> <p>Input: "Bolo" (200 ohms). Bias provided for 8.7 ma bolometer or 1/100 amp fuse; or 4.3 ma low current bolometer. "Crystal". 200 ohms for crystal rectifier. "200,000 ohms". High impedance for crystal rectifier as null detector.</p> <p>Recorder Output: Jack provided for recording milliammeter having 1 ma full scale deflection, internal resistance of 1500 ohms or less.</p> <p>Input Connector: BNC</p> <p>Power: 115/230 volts $\pm 10\%$, 60 cps, 55 watts. Other frequencies on special order.</p>
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SECTION I

GENERAL INFORMATION

1-1 GENERAL DESCRIPTION

The Model 415B Standing Wave Indicator is a high-gain, tuned electronic voltmeter operating at a fixed audio frequency. It is designed primarily for use in making standing-wave measurements in conjunction with a suitable detector and slotted line or waveguide section. The Model 415B may also be used as a null indicator in bridge circuits and other applications requiring a sensitive fixed-frequency indicator. It is calibrated to indicate directly in SWR or in db when used with square-law devices such as crystal diodes (at low signal levels) and barretters. The Model 415B also has expanded scales for accurate reading of small increments.

Operating frequency of the Model 415B is determined by a single plug-in filter. The instrument is normally supplied for operation at 1000 cps $\pm 2\%$. The operating frequency may be changed in the field by installing a new plug-in filter tuned to the desired frequency. Plug-in filters for any single frequency between 315 and 2020 cps are available from the Hewlett-Packard Company; the frequency selected should not be harmonically related to the power line frequency.

1-2 INITIAL INSPECTION

After the instrument is unpacked, it should be inspected carefully for damage received in transit.

If any shipping damage is found, refer to the "Claim for Damage in Shipment" page in this manual.

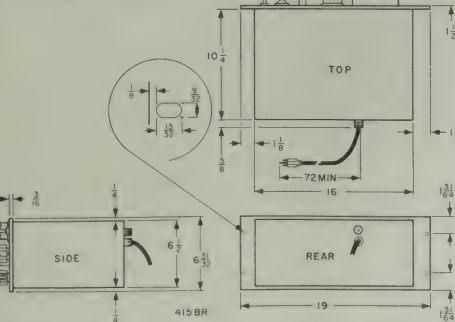
1-3 POWER CABLE

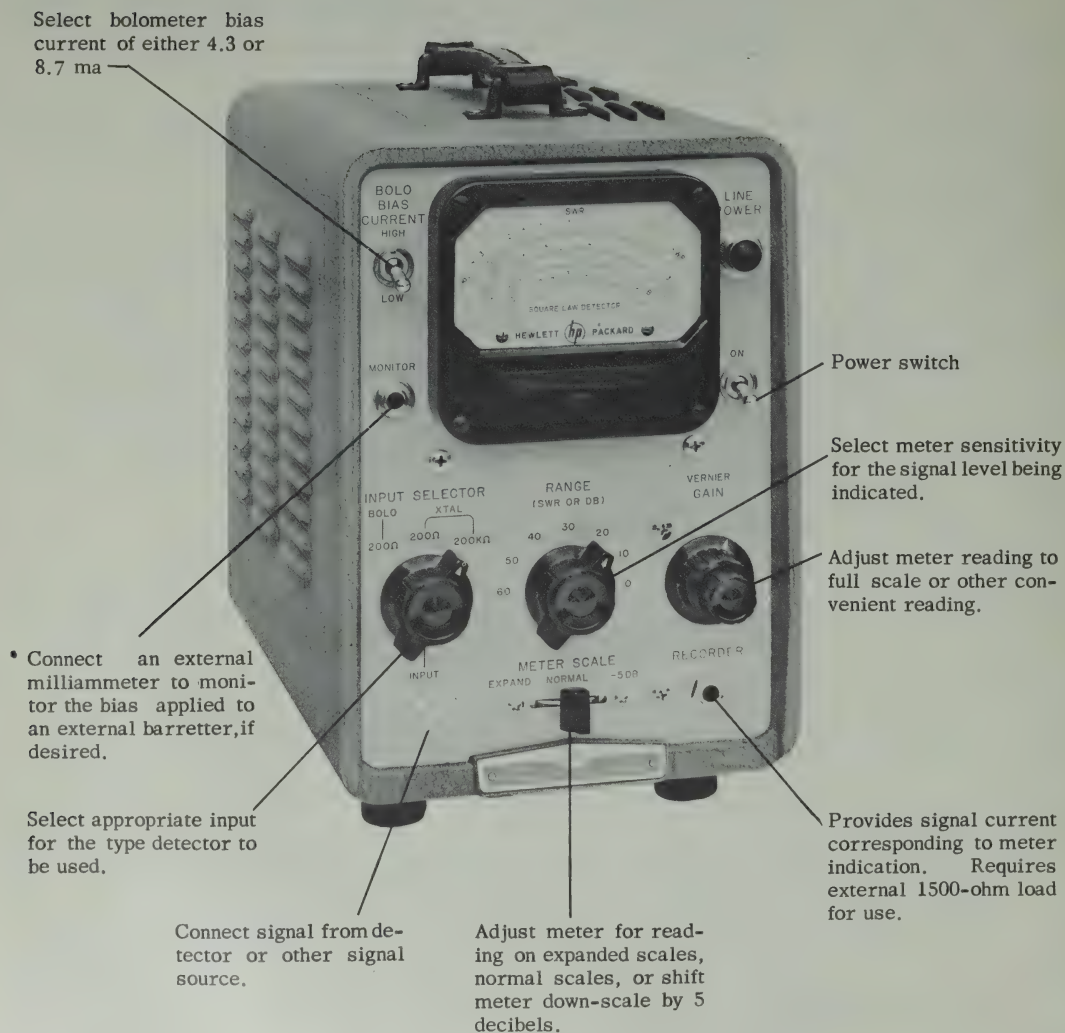
The three-conductor power cable supplied with this instrument is terminated in a polarized three-prong male connector recommended by the National Electrical Manufacturers' Association (NEMA). The third contact is an offset round pin which grounds the instrument chassis when used with an appropriate receptacle. To use this NEMA connector in a two-contact receptacle, a three-prong to two-prong adapter should be used. When the adapter is used, the round pin is terminated in a short green lead from the adapter which can then be connected to a suitable ground.

1-4 230-VOLT OPERATION

This instrument is normally wired for operation from a 115-volt power source. For operation from a 230-volt power source, the dual 115-volt primary windings on the power transformer are connected in series. Refer to the schematic diagram for proper connections. After converting the instrument, change the power line fuse to the size specified in the Table of Replaceable Parts (section V) for 230-volt operation.

Table 1-1. Specifications (cont'd)

Dimensions:	Weight:
Cabinet Mount: 7-1/2 in. high, 11-3/4 in. high, 12-1/2 in. deep.	Cabinet Mount: Net 13 lbs., shipping 19 lbs.
Rack Mount:	Rack Mount: Net 17 lbs., shipping 29 lbs.
	Accessories Furnished: 41A-16E Cable Assembly
	Accessories Available: 415B-42B Plug-in Filter 315-700 cps 415B-42C Plug-in Filter 700-2020 cps
AC-16K Video Cable Assembly, 4 feet of RG-58/U 50-ohm coaxial cable terminated at each end with UG-88/U Type BNC male connectors.	AC-16D Cable Assembly, 44 inches of RG-58/U 50-ohm coaxial cable terminated at one end only with UG-88/U Type BNC male connectors.



MP-S-512 B

Figure 2-1. Front Panel Control and Terminal

SECTION II

OPERATING INSTRUCTIONS

2-1 CONTROLS AND TERMINALS

Refer to Figure 2-1 for explanation of the panel controls and terminals.

2-2 AUXILIARY EQUIPMENT REQUIRED

A typical test set up for making SWR measurements is shown in Figure 2-2. The auxiliary equipment required with the Model 415B follows:

A. SIGNAL SOURCE

The signal source should cover the desired frequency range and be amplitude modulated at the operating frequency of the Model 415B. Generally, squarewave modulation is used which reduces to a minimum the effects of harmonics and frequency modulation. If the signal source is pulse-modulated, the duty cycle should be not less than approximately 40%. Short pulse type signals or poor quality square waves can introduce measurement errors in the Model 415B.

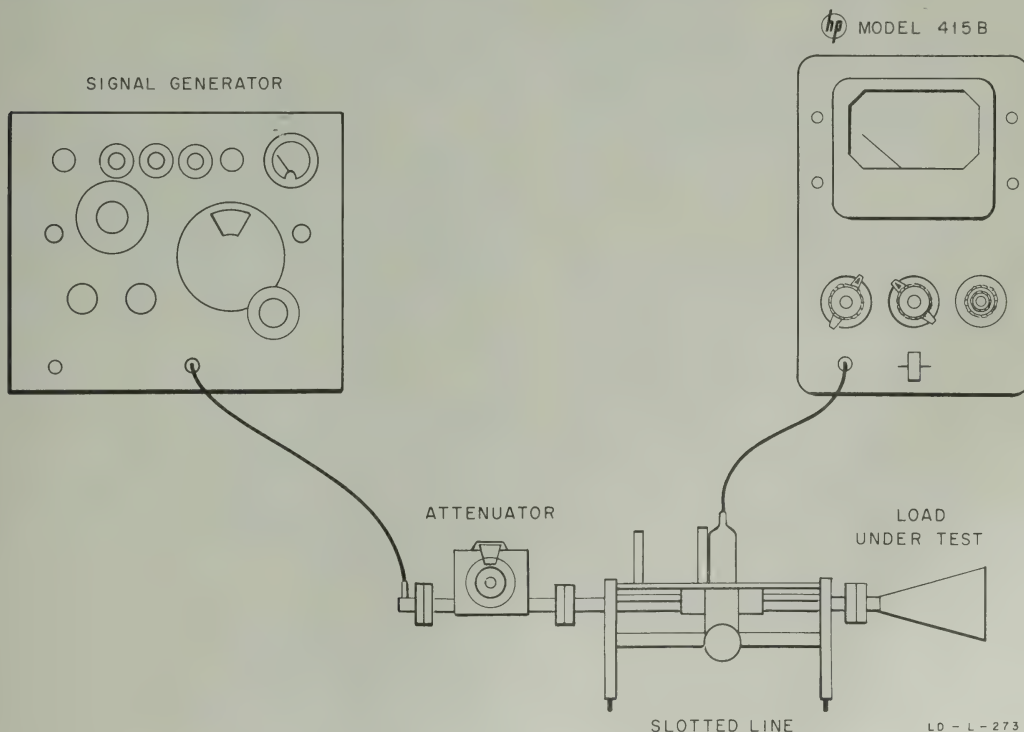


Figure 2-2. Test Setup

In many applications, it is necessary to minimize interaction between the oscillator and the load. In these cases, an isolating device should be used. For flexible and versatile operation, the signal source should indicate power output and should include an accurately calibrated attenuator.

B. CABLES OR WAVEGUIDES

The cable or waveguide used for connecting the source to a slotted section should match the source impedance over the desired frequency range.

C. SLOTTED SECTION

The slotted section should cover the desired frequency and be equipped with an accurate scale or indicator.

D. DETECTOR

The detector should be a square-law (output proportional to rf power input) device such as a barretter or a crystal diode operated at low signal levels. A barretter is reasonably square-law when used at low signal levels, but in general, this can not be said in all cases with crystal diodes. However, the sensitivity of crystals is considerably better than with barretters so that crystals are widely used as detectors for SWR measurements. See paragraph 2-5 when using crystal diode as detector.

E. KNOWN LOADS

Various terminations are required (i.e., a fixed and a movable short circuit) to establish reference points and to aid in calibrating the test set up.

2-3 TECHNIQUES IN SWR MEASUREMENTS

Basically, the measurement of a standing-wave ratio consists of setting the probe carriage at a voltage maximum position and setting the gain of the Model 415B to obtain a reading of 1.0. The probe carriage is then moved along the slotted line to a voltage minimum and the SWR is indicated directly on the scale of the Model 415B. This method, while straightforward and simple, may lead to serious errors under certain conditions. Paragraphs 2-4 through 2-9 discuss these errors and suggest techniques for minimizing their effects. In many cases only a knowledge of the SWR is required, but there are other cases, chiefly in design and development, where complete knowledge of the terminating equipment is desired. This can be obtained by measuring SWR and phase in the standing-wave pattern.

Generally, the impedance characteristic of the load is obtained by measuring the position of the voltage minimum. This position is compared to a shifted position of the voltage minimum which occurs when a known load replaces the load under test at a reference point on the slotted line. For convenience, the known load is usually a short circuit or shorting plate and the reference point is the load connection. The distance between these two minima is entered on a Smith Chart and the reactive component is determined. Detailed instructions for measuring the impedance characteristics of the load are given in paragraphs 2-10 through 2-13.

2-4 DETECTOR PROBE PENETRATION

A general rule in slotted line work is that the penetration of a sampling probe into the line should be held to a minimum. One of the major sources of error in SWR measurements is the failure to observe this rule.

The power extracted by the sampling probe causes distortion in the standing-wave pattern. This effect usually becomes greater as probe penetration is increased and can be explained by considering the probe as an admittance shunting the line.

Impedance in the standing-wave pattern varies along the line from maximum at a voltage maximum to a minimum at a voltage minimum. The shunt admittance introduced by the probe lowers these impedances, thus causing the measured SWR to be lower than the true SWR and shifting both the maxima and minima from their natural positions. The shift will be greater at a voltage maximum than at a voltage minimum.

Besides absorbing power and affecting the standing-wave pattern, the probe will also cause reflections in the line. These reflections will travel towards the signal source. If the signal source is not matched, these reflections are re-reflected toward the load and will cause additional errors in low SWR measurements.

An exception to the minimum penetration rule occurs when it is desired to examine in detail a voltage minimum in high SWR measurement. For this work, greater probe penetration can be tolerated because the voltage minimum corresponds to a low impedance point in the line. However, only at a voltage minimum can you tolerate substantial probe penetration.

2-5 PRECAUTIONS WHEN USING CRYSTAL DETECTORS

Whenever a crystal detector with a matched load resistor is used, the INPUT SELECTOR switch must be set at the XTAL-200K Ω position to obtain accurate square-law response. With an unloaded crystal, select the input impedance which gives maximum sensitivity. Usually the XTAL-200 Ω position will give the best sensitivity. However, some crystal diodes may give higher output in the XTAL-200K Ω position. Maximum sensitivity is desirable so probe penetration in the slotted line can be kept to a minimum.

There are precautions to be observed concerning all crystal detector elements. Crystal diodes exhibit a departure from the ideal square-law response for which the 415B is calibrated. This departure tends to occur when the rf power level exceeds a few microwatts. This corresponds to a reading of approximately fullscale on the 30-db range of the 415B with the gain controls set to maximum. In paragraph 2-7, methods of calibrating the detector are discussed.

2-6. OPERATING PROCEDURES

The operating procedures for the Model 415B Standing Wave Indicator are divided into two classifications (A) low SWR (10 and below) and (B) high SWR measurements. The step-by-step procedure for making these measurements follows:

Both MONITOR and RECORDER jacks on the front panel of the Model 415B receive the three-terminal 1/4 inch diameter "tip-ring-sleeve" phone plug supplied with the instrument. Do not use the standard single-circuit phone plug in these jacks. In both jacks the sleeve connection is grounded to the instrument chassis and is not used as part of the output circuit; the ring and tip provide the connections to the appropriate signal circuit and must not be grounded externally.

A. LOW SWR MEASUREMENTS (10 and below)

1) Turn instrument ON. For maximum stability allow approximately 10 minutes warm-up.

- 2) Set INPUT SELECTOR switch for the type of detector that is to be used.
- 3) Connect the detector cable to the INPUT.
- 4) Set GAIN and VERNIER controls to approximately 3/4 maximum.
- 5) Set RANGE switch on 30-db or 40-db position. Adjust probe penetration to obtain up-scale reading.
- 6) Peak the meter by adjusting the modulation frequency of the signal source, if adjustable. Reduce probe penetration to keep meter on scale.
- 7) Peak the meter by tuning the probe detector, if tunable. Reduce probe penetration to keep meter on scale.
- 8) Peak the meter by moving the probe carriage along the line. Reduce probe penetration to keep meter on scale.
- 9) Adjust GAIN controls and/or output power from the signal source to obtain exactly full-scale reading.
- 10) Move the probe carriage along the line to obtain a minimum reading. Do not retune probe or detector circuit.
- 11) Read SWR, which is indicated directly on the 415B. The following examples refer to Figure 2-3.

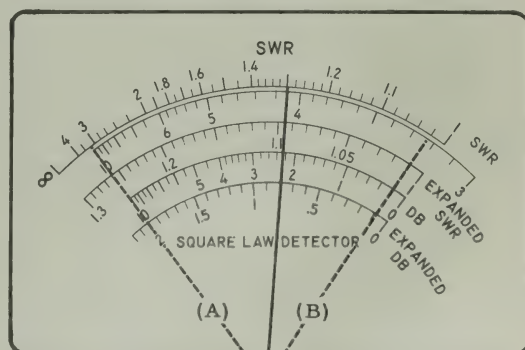


Figure 2-3. Detail of Meter Face

- a. If the reading at the minimum is lower than 3 on the top scale (dashed pointer line A in Figure 2-3), set RANGE switch to next (40-db or 50-db) range and read the indication on the second SWR (3 to 10) scale. In Figure 2-3, the reading is 3.25 (dashed pointer line B).

b. If the RANGE switch is changed by two steps, use the top SWR scale; however, all indications on this scale must be multiplied by 10.

c. If the SWR is 1.3 or less, it can be read on the EXPANDED SWR or EXPANDED DB scale after the METER SCALE switch is set to EXPAND and steps 8, 9, 10 and 11 are repeated. In the EXPANDED position, set RANGE switch to next (40-db or 50-db) range and readjust GAIN control to obtain a reading of full-scale at the voltage maximum.

d. The standing-wave ratio may also be expressed in decibels using the DB and EXPANDED DB scales. If the SWR is between 5 and 10 on the DB scale, set METER SCALE switch to -5DB and set RANGE switch to next lower (CCW) range. To obtain a true reading, subtract 5 db from the indication on the DB scale.

A graph of SWR in decibels vs. voltage standing-wave ratio is shown in Figure 2-4.

For accurate measurements, it is good practice to take several readings with different amounts of probe penetration to detect any probe loading error in the standing-wave pattern.

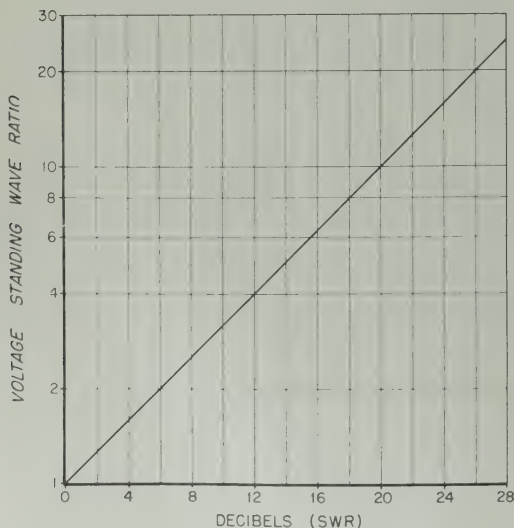


Figure 2-4. Graph Showing Standing Wave Ratio in DB vs. SWR

B. HIGH SWR MEASUREMENTS (above 10)

The straightforward measurement of SWR with conventional methods is generally applicable when measuring nominal SWR's up to 10, but at higher SWR's special techniques are desirable.

When the SWR is high, probe coupling must be increased if a reading is to be obtained at the voltage minimum. However, at the voltage maximum this high coupling may result in a deformation of the pattern, with consequent error in reading. In addition to this error caused by probe loading, there is also danger of error resulting from the change in detector characteristics at higher rf levels.

C. DOUBLE MINIMUM METHOD

In the double minimum method, it is necessary to establish the electrical distance between the points where the output is double the minimum (see Figure 2-5).

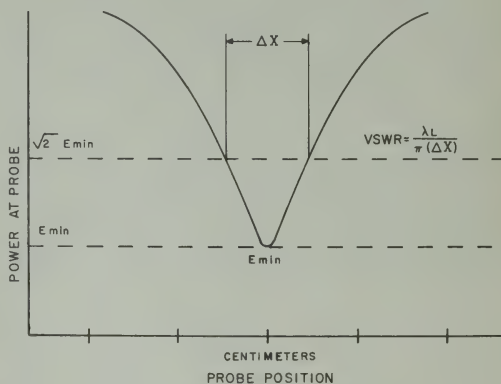


Figure 2-5. Graph Showing Double Minimum Method for Computing SWR

1) Repeat steps 1 through 7 in the Low SWR Measurement procedure.

2) Move the probe carriage along the line to obtain a minimum reading and note the probe carriage position.

3) For reference, adjust gain controls to obtain a reading of 3.0 on the DB scale. If a linear detector is being used, adjust GAIN controls for an indication of 1.5 on the DB scale.

- 4) Move the probe carriage along the line to obtain a reading of full-scale ("0") on the DB scale on each side of the minimum.
- 5) Record as d_1 and d_2 , the probe carriage positions at the two equal readings obtained in step 4.
- 6) Short the line and measure the distance between successive minima. Twice this distance is λ_L , the guide wavelength.

The SWR can then be obtained by substituting this distance into the expression:

$$\text{SWR} = \frac{\lambda_L}{\pi(d_1 - d_2)} = \frac{\lambda_L}{\pi(\Delta X)}$$

Where λ_L is the guide wavelength; d_1 and d_2 are the locations of the twice-minimum points.

This method overcomes the effect of probe loading since the probe is always set around a voltage minimum where larger probe loading can be tolerated. However, it does not overcome the effect of detector characteristics.

D. CALIBRATED ATTENUATOR METHOD

Another method for measuring high SWR's is to use a calibrated variable rf attenuator between the signal source and the slotted line. Adjust the rf attenuator to keep the rectified output of the crystal diode equal at the voltage minimum and voltage maximum points. The SWR in db is the difference in the attenuator settings.

- 1) Repeat steps 1 through 7 in Low SWR Measurements procedure.
- 2) Move the probe carriage along the line for a voltage minimum, adjust the rf attenuator to give a convenient indication on the meter, and note the rf attenuator setting.
- 3) Move the probe carriage along the line to a voltage maximum, adjust the rf attenuator to obtain the same indication on the meter as established in step 2, and note the rf attenuator setting.
- 4) The SWR may be read directly (in db) as the difference between the first and second readings.

While this method overcomes the effect of detector variations from a square-law characteristic, the effect of probe loading still remains. Be careful; always use minimum probe penetration.

2-7 CHECKING OF SQUARE-LAW RESPONSE

The square-law response of either a crystal diode or bolometer is easily checked with slotted line equipment.

A simple method of calibrating a detector is by increasing the power level in the slotted line in known steps and noting the detector response on the Model 415B.

Another method for calibrating a detector is to use a load having unity reflection coefficient (usually a short circuit). This load will then set up an electric field between adjacent minima in the slotted line closely approximating half a sine wave, thus giving a relative voltage that is a known function of the probe carriage position. *

Any new crystal being used for the first time should be checked, as there is often a significant variation between crystals. Data should be taken in both XTAL positions on the Model 415B, so that the better setting may be determined for any individual crystal diode.

2-8 LOCATION OF VOLTAGE MAXIMUM OR VOLTAGE MINIMUM

From the discussion on probe loading it has shown that it is more desirable to locate the voltage minimum than the voltage maximum since the effect of probe loading is less at the minimum. However, the location of a voltage minimum by a single measurement, particularly on low SWR, is usually inaccurate because of its broadness, thus making the true minimum position hard to determine. An accurate method of locating the voltage minimum is to obtain the position of the probe carriage at two equal output readings on either side of the minimum and then averaging these two readings.

2-9 PRECAUTIONS WITH SIGNAL SOURCES

Signal sources can introduce at least three undesirable characteristics that will affect slotted line measurements. These include presence of rf harmonics, frequency modulation, and spurious signals. Signal sources used for standing wave measurements should have relatively low harmonic content in their output. The standing wave ratio

*Ginzton, Edward L., "Microwave Measurements", pp. 142-144, McGraw-Hill Book Company, Inc., New York, N.Y. 1957

at a harmonic frequency may be considerably higher than at the fundamental. Spurious frequencies in the signal source are also undesirable, for, unless very slight, they will obscure the minimum points at high SWR values. Figure 2-6 shows plot of an SWR pattern made with signal source producing unwanted fm.

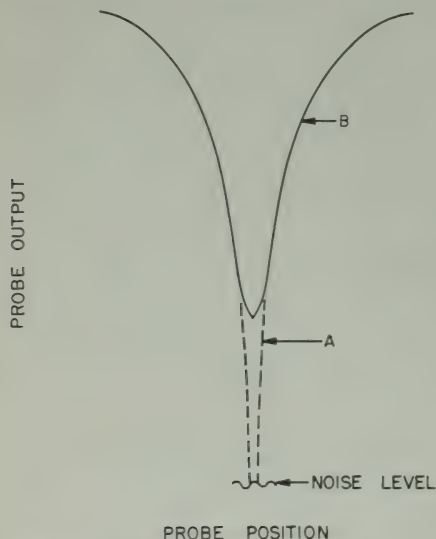


Figure 2-6. High Standing Wave Ratio Pattern
(A) Free of FM
(B) With Moderate FM

Instances are common where the presence of rf harmonics has led to very serious errors in SWR measurements. Such harmonics are usually present to an excessive degree only in signal sources that have coaxial outputs. Coaxial pickups of a broad-band type will often pass harmonic frequencies with greater efficiency than the fundamental. In waveguide systems, signal sources such as internal cavity klystrons have a more or less fixed coupling and in addition do not have pickups extending into the tuned cavity to cause perturbations of the cavity fields. Consequently, the harmonic problem is generally limited to coaxial systems. Harmonics become especially troublesome when the reflection coefficient of a load at a harmonic frequency is much larger than at the fundamental frequency--a common condition. When the harmonic content of the signal source is high, the large reflection coefficient of the load at the harmonic frequency can cause the harmonic standing wave fields to be of the same order of magnitude as the fields at the fundamental frequency.

Thus, a device having a SWR of 2.0 at the fundamental frequency will often have a SWR of 20 or more at the second harmonic frequency. If such a device is driven from a signal source having, say, 15% second harmonic content, the peaks of the standing waves of second harmonic will be about one-fourth the amplitude of the peaks at the fundamental frequency. Figure 2-7 shows a typical SWR pattern obtained when the rf signal contains harmonics.

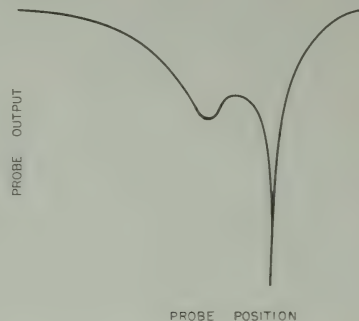


Figure 2-7. Typical Pattern of High SWR Spurious Frequency in Signal Source

2-10 IMPEDANCE MEASUREMENT RULES

Some rules of thumb that are helpful in making slotted line measurements are:

- 1) The shift in the minimum when the load is shorted is never more than \pm one quarter wavelength.
- 2) If shorting the load causes the minimum to move toward the load, the load has a capacitive component.
- 3) If shorting the load causes the minimum to shift toward the generator, the load has an inductive component.
- 4) If shorting the load does not cause the minimum to move, the load is completely resistive and has a value Z_0/SWR .
- 5) If shorting the load causes the minimum to shift exactly one-quarter wavelength, the load is completely resistive and has a value of $Z_0 \times \text{SWR}$.
- 6) When the load is shorted, the minimum will always be a multiple of a half-wavelength from the load.

Shifts in voltage minima resulting from various types of loads are illustrated in Figure 2-8.

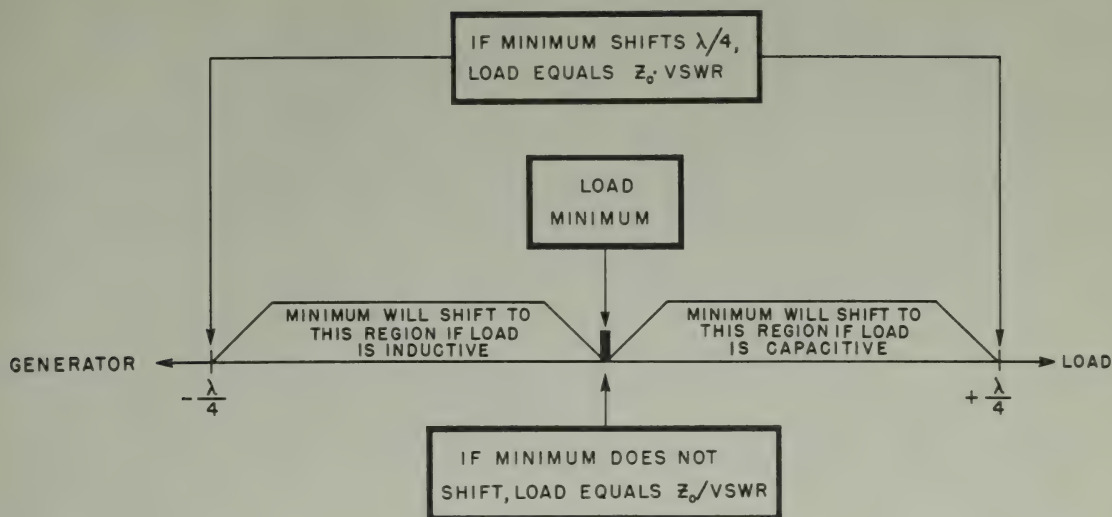


Figure 2-8. Summary of Rules for Impedance Measurement

2-11 IMPEDANCE MEASUREMENT PROCEDURE

The technique for performing actual impedance measurement is as follows:

1) Connect the load under test to the slotted section and measure the SWR and the position of the minimum in the standing wave pattern.

2) Replace the load with a short at the load end of the slotted line.

3) Determine the new minimum position with the line shorted.

4) The normalized load impedance may be computed by the formulas below. Refer to Figure 2-9.

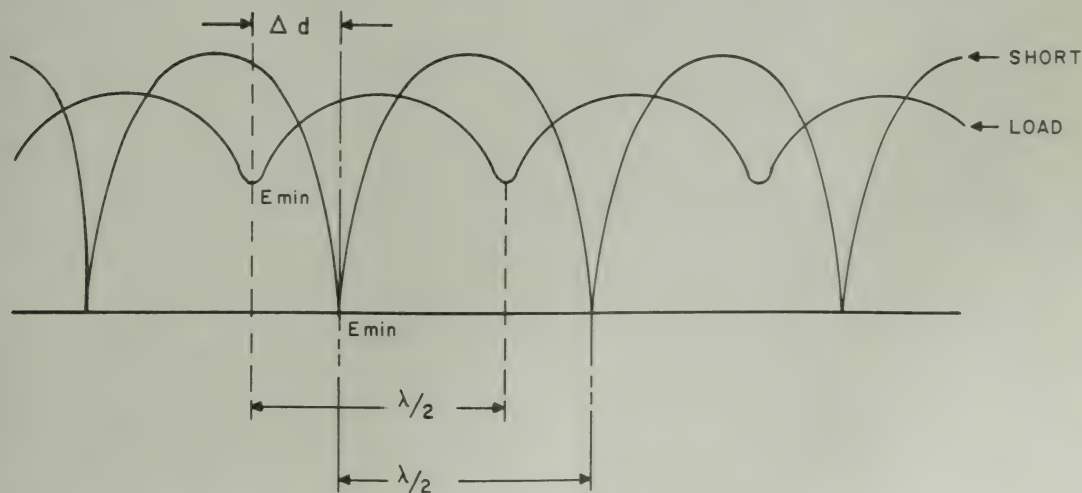


Figure 2-9. Graph Showing Standing Wave Patterns with a Load and Short

$$z L = \frac{1 - j(\text{SWR}) \tan X}{(\text{SWR}) - j \tan X}$$

$$\text{Where: } X = \frac{180^\circ (\pm \Delta d)}{\frac{\lambda}{2}}$$

And: $\pm \Delta d$ = Shift in centimeters of the minimum point when the short is applied.

Δd takes a positive (+) sign when the minimum shifts toward the load.

Δd takes a negative (-) sign when the minimum shifts toward the generator.

$\frac{\lambda}{2}$ = One-half line or guide wavelength. It is the distance in centimeters as measured between two adjacent minima.

These calculations are based upon the assumption that no losses occur in the transmission system. For laboratory set-ups where the line lengths are short this assumption is customary. It is also assumed that the Z_0 for the lines is entirely resistive.

2-12 IMPEDANCE MEASUREMENT AND THE SMITH CHART

When data is obtained from slotted line measurement, one of the most indispensable tools and certainly the simplest to use, is the Smith Chart. This chart represents an impedance coordinate system so arranged that the variable quantities in impedance relationships are conveniently displayed for the solution of transmission line problems.*

The values of resistance and reactance shown on the Smith Chart in Figure 2-10 are based upon the normalized values. The normalized impedance, resistance or reactance is obtained by dividing the actual value by the characteristic impedance of the line. For example, if the actual impedance of a 50 ohm transmission line were found to be 100 ohms at some point, the normalized impedance would be 2.

The circles on the Smith Chart tangent to bottom of the chart are circles of constant and normalized resistance.

The straight line forming the vertical diameter of the chart is the line of zero reactance. To the right and left of this line are seen lines which curve away from the zero reactance line. The curved lines to the right are the lines of positive reactance $\frac{+jX}{Z_0}$.

The curved line to the left are the lines of negative reactance, $\frac{-jX}{Z_0}$.

For example, the impedance point of a line terminated by its characteristic impedance would be the center of the chart (with a normalized resistance of 1.0 and no reactive component).

In another example of actual impedance calculation:

$$ZL = 5 + j25 \text{ ohms}$$

Normalized for a 50 ohm line would be:

$$zN = 0.1 + j0.5$$

2-13 PROCEDURE FOR SMITH CHART CALCULATIONS

The step by step procedure for employing the Smith Chart when solving transmission line problems is outlined below. It should be understood that there are various methods employed for entering the Smith Chart with data obtained from the slotted line, and that the method outlined in this section has been found practical and simple.

- 1) Set up slotted line in system.
- 2) Measure SWR in manner described in section 2-6.
- 3) Determine wavelength of transmission line (λL). The distance as measured on slotted line between two adjacent minima is equal to one-half the wavelength of the line.
- 4) Find a convenient minimum point.
- 5) Replace load with short.
- 6) Measure Δd (the shift in centimeters of the minimum point with the short applied).

*Smith, P.H. "Transmission-line Calculator" Electronics, Jan. 1939, McGraw Hill.

- 7) Determine the number of wavelength of shift ($\Delta\lambda$).

$$\Delta\lambda = \frac{\Delta d}{\lambda L}$$

- 8) Starting at center of Smith Chart draw circle with SWR as radius. Read SWR on zero reactance line down from center.

- 9) Enter the Smith Chart at the top and proceeding in a direction of probe movement (either toward the load or toward the generator) when the load was replaced by a short to the quantity $\Delta\lambda$ established in step 7.

- 10) Draw a line to the center of the chart from the $\Delta\lambda$ point.

- 11) The intersection of this line and the SWR circles is the normalized impedance.

- 12) It is important that the convention be followed of first finding the minimum reference with the load on the line and then sliding the probe to the new minimum when the line is shorted. Should it be necessary to establish the shorted minimum point first, the Smith Chart would be entered with $\Delta\lambda$ in a direction opposite to the direction of probe movement. That is, the probe movement toward the load would be entered on the chart in a direction toward the generator.

- 13) The following is an example to clarify the previous procedure (refer to figure 2-10):

The SWR measured is 3.3.

Distance between two adjacent minima is 15 cm. Therefore, wavelength of the line is 30 cm (λL).

A convenient minimum is located at 22 cm.

When the line is shorted the minimum point shifts to 19 cm (toward generator).

$$\Delta d = 22 - 19$$

$$\Delta d = 3 \text{ cm}$$

$$\Delta\lambda = \frac{\Delta d}{\lambda L}$$

$$\Delta\lambda = \frac{3}{30}$$

$$\Delta\lambda = 0.1 \text{ wavelength}$$

Construct SWR circle on Smith Chart (1).

Construct radius to wavelength shift point (2).

Read normalized impedance at intersection of circle and radius (3).

In this example the normalized impedance is $0.44 + j0.63$. Assuming a characteristic impedance of 50 ohms, the load impedance, Z_L , is:

$$Z_L = 50 (0.44 + j0.63)$$

$$Z_L = 22 + j31.5 \text{ ohms}$$

2-14 USING THE 415B WITH AN OSCILLOSCOPE

With the 415B RECORDER jack at normal there is a 1500-ohm resistor (R37) across the tip and ring leads of the jack. With a plug in the jack, R37 is open. For proper operation of the 415B, therefore, it is necessary to connect a 1500-ohm resistor across the tip and ring of the plug when connecting the 415B to a high-impedance instrument like an oscilloscope.

Use a three-conductor plug, such as a Switchcraft No. 60, and connect a 1500-ohm 1/4 watt resistor across the tip and ring terminals (see Figure 2-9A). Be sure the resistor is not connected across the tip and sleeve (ground); if the external 1500-ohm resistor is connected to ground, part of the meter feedback circuit will be shunted to ground.

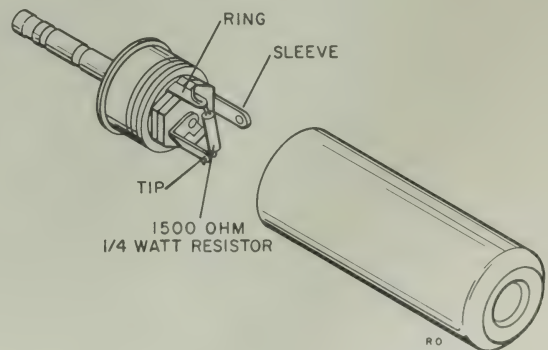


Figure 2-9A. Three-Conductor Plug Connection

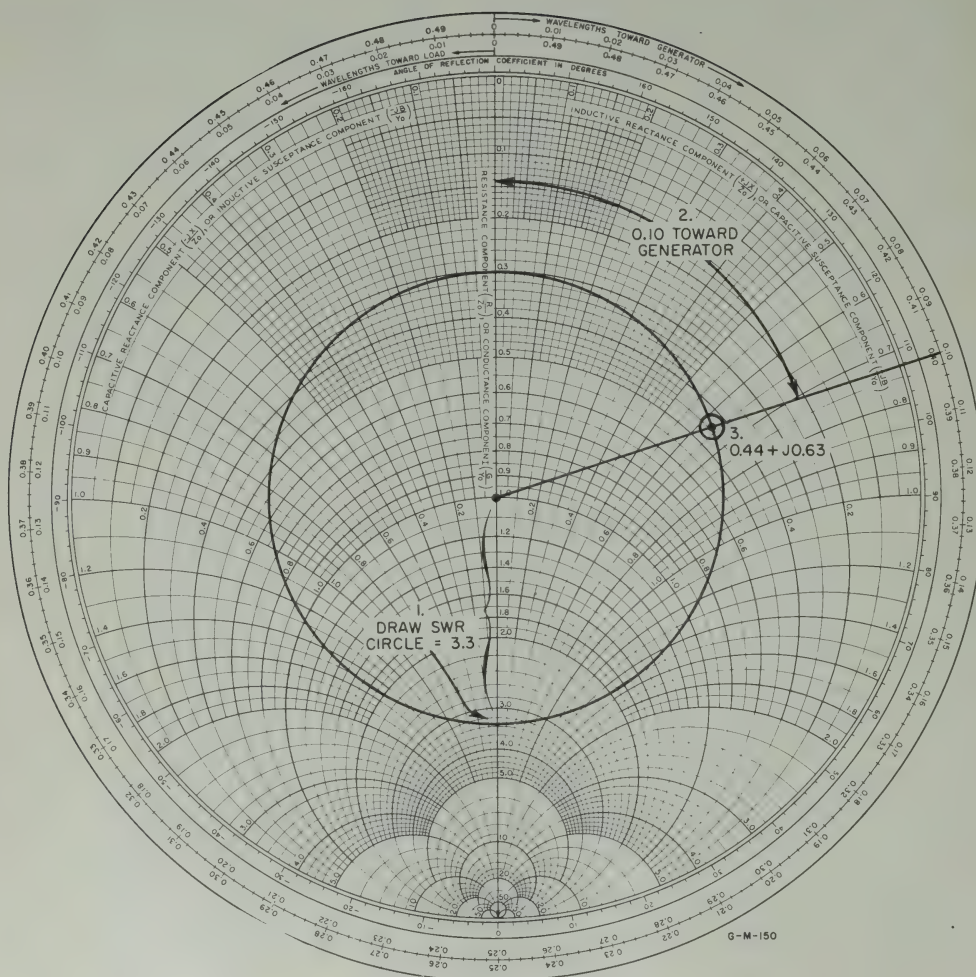


Figure 2-10. Smith Chart Showing Normalized Impedance

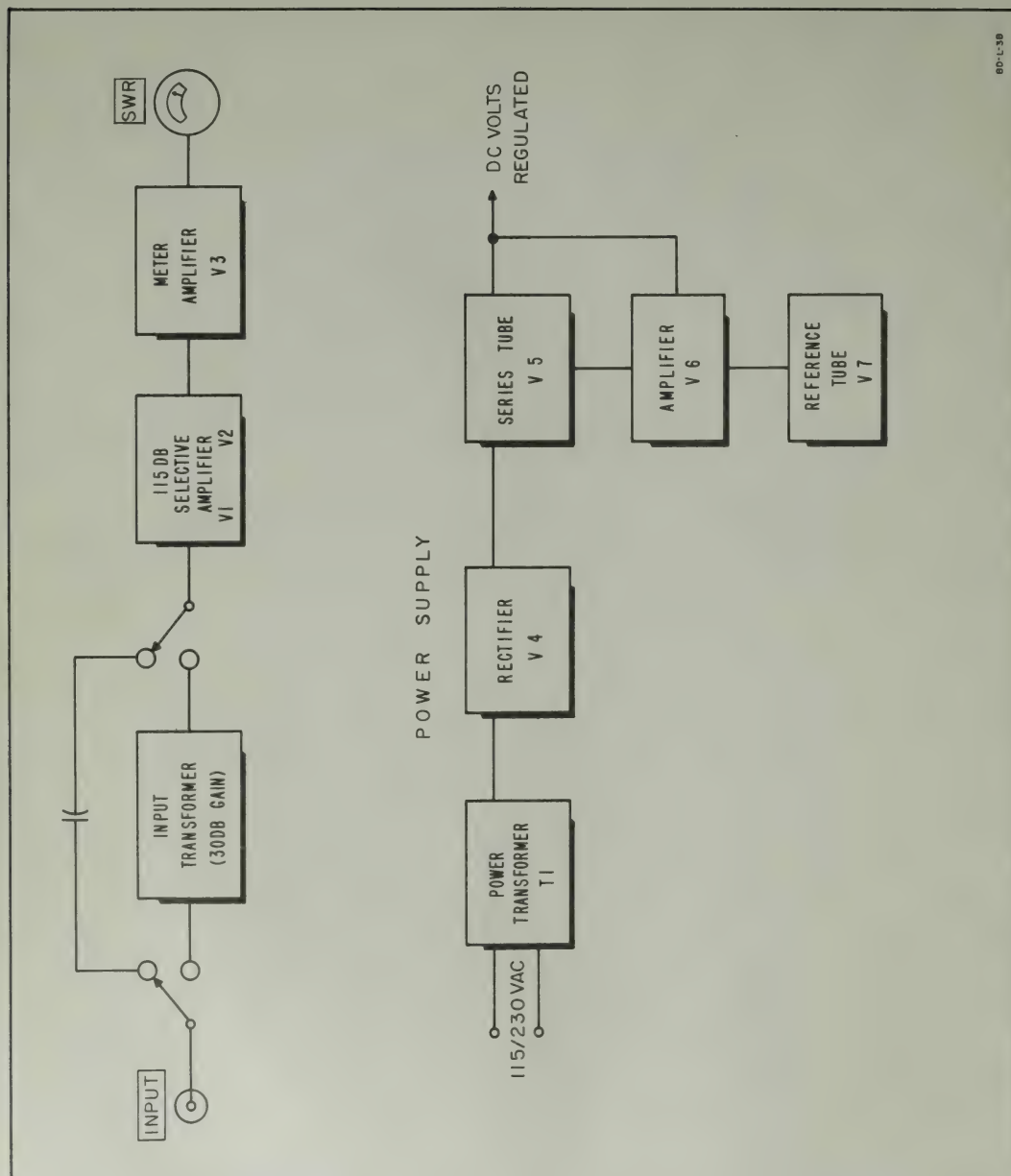


Figure 3-1. Model 415B Block Diagram

SECTION III

PRINCIPLES OF OPERATION

3-1 CIRCUIT DESCRIPTION

The Model 415B Standing Wave Indicator consists of a high-gain amplifier with very low noise level, a plug-in filter, an indicating meter and an electronic regulated power supply. All tubes of the instrument are shown in block diagram in Figure 3-1.

3-2 FREQUENCY SELECTIVE AMPLIFIER

The frequency selective amplifier consists of a step-up input transformer, T2, four resistance-coupled amplifier stages and a fourth stage drives a Fixed-frequency filter. The amplifier without the input transformer provides a total gain of 115-db gain, while T2 provides an additional 30 db.

The input circuit to an amplifier is arranged to match various external signal sources such as a crystal diode, barretter or a relatively high-impedance device (bridge circuit, etc.). When the input circuit is switched to XTAL-200K Ω the INPUT jack connects through the RANGE switch, S5, to the grid of the first amplifier stage. In the XTAL-200 Ω position, the INPUT jack connects to the primary of T2 which provides a reflected load of 200 ohms to any device connected to the INPUT jack.

In BOLO position the INPUT jack connects to the primary of the input transformer as above; except that the primary winding is now returned to R2 and R3 which provide dc operating bias to any 200 detector element connected to the INPUT. Diodes CR3 through CR6 maintain the voltage at the INPUT jack at a low level to reduce the transient current from C2 when a detector element is connected. The HIGH-LOW switch shunts the bias source with R1 so that two different values of bias (4.3 and 8.7 ma) may be used. The MONITOR jack is supplied so that an external milliammeter may be used to measure the bias current passing through the detector.

The RANGE switch, S5, consists of a three-section step attenuator which changes the gain of the amplifier in 20-db steps. However, to obtain square law meter calibration, the steps are calibrated 10 db on the front panel. The three sections of the attenuator are located in the grid circuits of the first three amplifier stages, V1A, B and V2A. The third section provides the first attenuation step, the second section the second attenuation step and the first section provides the remaining four attenuation steps. Selected precision resistors are used throughout the range switch. Because of the extremely high gain in this amplifier, the grounding of all parts in the first and second stages is very critical and specially indicated on the schematic diagram. The heavy lines indicate common negative tie points which in turn are together and connected to chassis only at J1.

The output level from the amplifier is controlled by a two-section potentiometer (GAIN, R22A and VERNIER, R22B.) in the grid circuit of the last amplifier stage. The potentiometers are connected in series, one providing approximately 25 db (12.5 db on the meter scale) of control for coarse adjustments, the other approximately 1.5 db (0.75 db on the meter scale) of control for fine adjustments.

Switch S4a between the second and third amplifier stages, when in the -5 db position, reduces the sensitivity of the amplifier to decrease the SWR meter indication by 5 db so that down-scale meter readings may be made upscale on the next lower range of the RANGE switch.

To make the amplifier frequency selective, the plate circuit of the last stage is loaded with parallel resonant circuit, Z1, having an effective Q between 20 and 30. The tuned circuit allows a 1000-cps signal to pass unattenuated, while the decreased impedance at off resonant frequencies attenuates these frequencies considerably. The effective bandwidth is approximately 40 cycles at the half-power points.

3-3 METER CIRCUIT

The 1000-cps signal from the selective amplifier is applied to a two-stage feedback amplifier which operates crystal rectifiers CR1, CR2 and the indicating meter M1. To assure linear operation, negative feedback is used around both the amplifier and the rectifier circuit. A 0.46-volt rms signal is required at the first grid of V3 to obtain a full scale meter indication. The signal from the second plate of V3 is fed to crystal diode CR2 which allows current to flow through R37 and the meter during the negative half of the signal cycle. During the positive half cycle the current returns through CR1 and R36.

Front panel selector S4, when set to the EXPAND position, applied a dc bucking voltage to the meter rectifiers so that a meter reading is forced off-scale, i.e., downward. The amplifier sensitivity must then be increased to obtain an upscale reading; which can then be read on the expanded meter scales.

3-4 POWER SUPPLY

The power supply consists of a power transformer with a single high-voltage winding feeding a full wave rectifier and electronic voltage regulator supplying dc to all the circuits of the standing wave indicator. The voltage regulator circuit maintains constant output voltage with wide changes in load current and line voltage.


V5, V6 and V7 constitute the voltage regulator circuit. V7 is a 'constant-voltage tube which provides the reference bias for V6. V5 operates as a series tube, or variable resistor, controlled by the voltage at the grid of V6. If the regulated B+ at the cathode of V5 tends to increase, the grid voltage for V6 increases causing V6 to draw more current. This lowers the plate voltage of V6 and therefore the grid voltage of V5 and results in greater plate resistance for V5. The greater plate resistance causes a greater voltage drop across V5, compensating for the increased voltage at its cathode and resulting in a substantially constant voltage output.

If the regulated B+ voltage tends to decrease, the reverse of the above action occurs, also tending to maintain the cathode voltage substantially constant. Ripple in the output voltage is coupled to the grid of V6 by capacitor C12. Variations in the dc voltage are coupled to the grid of V6 through the voltage divider R44, R45 and R46. The bias for V6 and the level of the output voltage from V5 are determined by the setting of R45.

The heaters of amplifier tubes V1, V2 and V3 are operated from a positive biased heater winding to reduce hum pickup from the heaters on these tubes. The bias voltage is obtained from a 10 volt point on the voltage divider stick R44, R46 and R48 in the power supply.

SECTION IV MAINTENANCE

4-1 INTRODUCTION

This section contains instructions for adjustment and repair of the  Model 415B Standing Wave Indicator. The information in this section is as follows:

- 4-2 Trouble Shooting the 415B
- 4-3 Replacing Tubes
- 4-4 Replacing Crystal Diodes
- 4-5 Range Switch Repairs
- 4-6 Equipment Required for Test and Adjustment
- 4-7 Test and Adjustment Procedure (General)
- 4-8 Set Meter Mechanical Zero
- 4-9 Adjust Regulated Power Supply
- 4-10 Check Monitor Jack
- 4-11 Check Sensitivity
- 4-12 Check Range Tracking
- 4-13 Check Noise Level
- 4-14 Calibrate Expanded Scale
- 4-15 Check -5DB Switch

4-2 TROUBLE SHOOTING THE 415B

The Model 415B is basically a high-gain, tuned amplifier with a "relative" indicating voltmeter. The instrument has few critical circuits. The maximum sensitivity may decrease as the tubes weaken with age but the accuracy will not be affected. Only adjustment of the power supply and/or recalibration of the EXPANDED scale is necessary after tube replacement.

The accuracy of the meter calibration is largely determined by crystal diodes CR1 and CR2. The mechanical tracking of the meter movement and the linearity of the amplifier affect meter calibration accuracy to a lesser degree. The amplifier linearity does not normally change.

Any unstable condition can usually be traced to the power supply. The power supply can be quickly checked by measuring the dc output voltage and by noting the noise level indication on the 415B meter.

An incorrect regulated voltage and/or a high residual noise level can be corrected by adjustment or by changing tubes. A high residual noise level that cannot be traced to the power supply can usually be corrected by replacing tube V1.

Individual stage gain measurements can be used to analyze an inoperative instrument. Gain can be checked by applying a small voltage (0.01 volt) from an audio oscillator to each stage in turn and measuring the stage output voltage. Set the audio oscillator to the same frequency as filter Z1 (usually 1000 cps). The approximate gain from each stage is as follows:

STAGE	DB GAIN (approx.)
Input Transformer	30
V1a	34
V1b	27.5
V2a	31
V2b	22
V3	***

***Approximately a 0.46 volt rms signal at the input of V3 will give a full scale meter deflection.

4-3 REPLACING TUBES

The tubes in the Model 415B can be replaced without making any adjustments except for those in the regulated power supply. The EXPANDED scale calibration should be checked after replacement of V3. After changing tubes in the power supply, the output voltage of the power supply should be checked and adjusted. Control R45 should be adjusted to set the dc voltage between the chassis and the cathode of the series regulator tube.

When replacing V1, select a tube that minimizes the noise indication and if possible the microphonics also.

4-4 REPLACING CRYSTAL DIODES

Use diodes with a high front-to-back resistance ratio of several hundred to one or better when replacing diodes CR1 and CR2. Adjustments are not necessary following replacement of CR1 and CR2 except that the calibration of the EXPANDED scale should be checked.

4-5 RANGE SWITCH REPAIRS

The precision resistors on the RANGE switch are selected and matched for accuracy during manufacture. Attempted replacement of individual resistors is usually not practical. Replacement of the entire switch assembly is recommended as a time-saving measure and guarantee of maintaining the original calibration accuracy.

If replacement of a single resistor is necessary, the resistor must be very carefully selected to maintain attenuator accuracy. Avoid excessive soldering heat or twisting or bending of these resistor leads during installation.

4-6 EQUIPMENT REQUIRED FOR TEST AND ADJUSTMENT

The following test equipment is used for testing and adjusting the Model 415B Standing Wave Indicator during manufacture. Any equivalent test instruments can also be used.

---An Φ Model 200CD Wide Range Oscillator

---An Φ Model 400D, 400H, or 400L AC Vacuum Tube Voltmeter.

---A pair of Φ Model 350B Attenuators.

---An Φ Model 410B Vacuum Tube Voltmeter.

---An adjustable line voltage source with meter.

---An 0-10 dc milliammeter with a known internal resistance and connected to a three-circuit phone plug. Connect the positive terminal of the meter to the "ring" of a 1/4 inch diameter "tip-ring-sleeve" phone plug and the negative terminal to the "tip".

---A BNC connector with a 1 watt composition resistor connected between the center contact and the outer shell. The resistor value plus the resistance of the 0-10 dc milliammeter must equal 200 ohms.

---A pair of Φ Model AC-16A banana plug to banana plug shielded cables and an Φ Model AC-16B banana plug to BNC shielded cable.

4-7 TEST AND ADJUSTMENT PROCEDURE (General)

The procedures that follow are listed in a sequence that is most easily followed when all of the procedures are to be completed. In many cases, only one or two of the procedures will be needed and they can be done without completing all the other tests.

A ten to fifteen minute warm-up and a check of power supply output voltage is always recommended before making any other tests or adjustments.

The specifications for your Φ Model 415B Standing Wave Indicator are given in the front of this manual. The following test procedure contains extra checks to help you analyze a particular instrument. These extra checks and the data they contain cannot be considered as specifications.

NOTE

The Model 415B is calibrated for use with square law detectors such as crystals and barretters. The output voltage of these detectors varies directly with input power. The 415B compensates for this characteristic by being calibrated to indicate a 1 db change on the meter for a 2 db change in input voltage. Thus, each 10 db step on the 415B range switch represents a twenty db change in input voltage.

DURING ADJUSTMENT THE 415B INPUT SIGNAL IS CONTROLLED BY AN EXTERNAL ATTENUATOR CALIBRATED IN DB. THE INDICATION ON THE 415B WILL CHANGE ONE DECIBEL FOR EACH TWO DECIBELS CHANGE IN THE EXTERNAL ATTENUATOR SETTING.

4-8 SET METER MECHANICAL ZERO

Turn the 415B ON long enough for the meter movement to reach the ambient temperature within the cabinet. Turn the instrument OFF and set the mechanical zero while the meter is still warm.

Rotate the meter mechanical zero adjusting screw clockwise until the meter pointer is traveling to the left toward 1.3 on the EXPANDED SWR scale and stop at 1.3. If you overshoot, continue rotating the adjustment screw clockwise and again approach from the high side of the scale. The adjustment screw should not be turned counter-clockwise during any part of this adjustment.

4-9 ADJUST REGULATED POWER SUPPLY

Connect the 410B VTVM with cathode (pin 3) of series regulator tube V5 and chassis ground. Adjust control R45 for a voltmeter reading of 245 volts dc with the line voltage set to 115 volts. As the line voltage is varied between 103 and 127 volts, the reading on the voltmeter will normally not change by more than $\pm 1\%$.

4-10 CHECK MONITOR JACK

Insert the phone plug from the 0-10 dc milliammeter into the MONITOR jack. Attach the BNC connector with resistor to the INPUT. The milliammeter connections and the resistor value are given in paragraph 4-6.

Set the INPUT SELECTOR switch to BOLO. The milliammeter will usually indicate 8.4 ± 0.4 milliamperes with the BOLO BIAS CURRENT switch in the HIGH position or 4.3 ± 0.3 milliamperes with the switch in the LOW position.

If the currents are incorrect, check resistors R1, R2, and R3 as well as the power supply output voltage.

4-11 CHECK SENSITIVITY

Connect your test equipment as shown in Figure 4-1. The ac vtvm should be connected to the output of the attenuator set.

NOTE

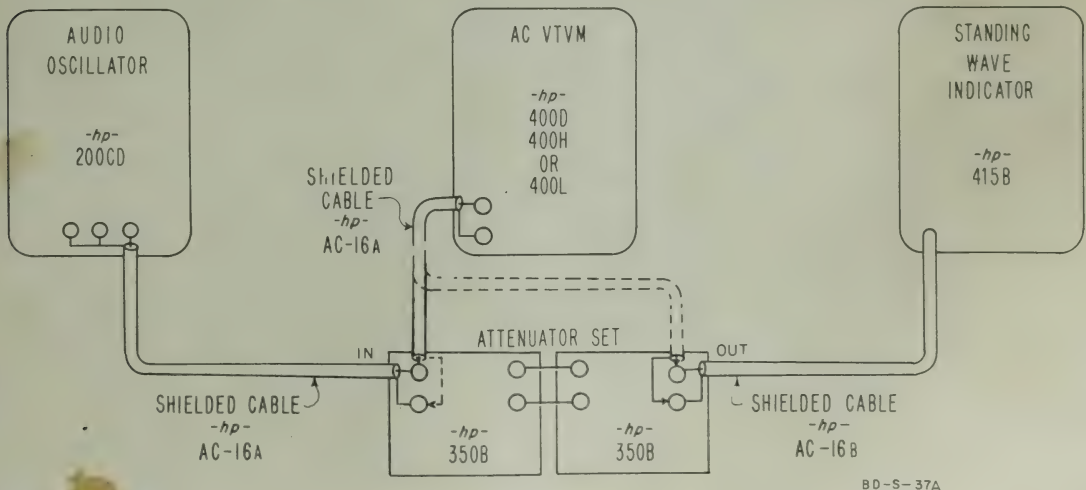
Several precautions must be used if you wish accurate results when using the Figure 4-1 test set-up. At least 20 db of attenuation should be inserted in the attenuator set at all times. The maximum attenuation inserted by either attenuator should not be over 80 db. The Model 415B chassis connection through the third wire in the NEMA type power cord should be disabled by using a three-prong to two-prong polarized adapter. The only ground connection to the 415B must be through the shielded cable from the attenuator set.

Rotate the Model 415B GAIN control fully clockwise and the RANGE switch to 0 DB. Set the input switch to XTAL 200 Ω and the METER SCALE switch to the NORMAL position.

Tune the audio oscillator to the Model 415B filter frequency as indicated by maximum deflection of the 415B meter. Adjust the audio oscillator output to obtain a full scale indication on the 415B. The indication on the ac vtvm should be 0.1 volt or less.

The basic sensitivity of the Model 415B can be obtained by dividing the meter indication by 1,000,000. Each position of the 415B range switch multiplies the sensitivity by 10 or by 1,000,000 when you switch directly from the 0 DB to the 60 DB switch position.

If the basic sensitivity is found to be low, try several replacement tubes for V1, V2, and/or V3.



BD-S-37A

Figure 4-1. Instrument Connections for 415B Test and Adjustment

4-12 CHECK RANGE TRACKING

Connect the test equipment as shown in Figure 4-1. Connect the ac vtvm to the input of the attenuator set.

Rotate the Model 415B GAIN control fully clockwise and the RANGE switch to 0 DB. Set the input switch to XTAL 200 Ω and the METER SCALE switch to NORMAL.

Tune the audio oscillator to the 415B filter frequency as indicated by maximum deflection of the 415B meter. Adjust the audio oscillator output for a full scale indication of "0" on the db scale. Note the indication on the ac vtvm and adjust the output of the audio oscillator to keep this reading constant.

Add 20 db attenuation in the attenuator set and rotate the 415B RANGE switch to 10 DB. The 415B meter should again indicate 0 db \pm 0.1 db.

Repeat this procedure for each step of the 415B RANGE switch. The 415B meter should indicate within \pm 0.2 db of the full scale 0 db mark on all six ranges. Adjacent ranges should read within \pm 0.1 db of each other.

4-13 CHECK NOISE LEVEL

Connect the test equipment as shown in Figure 4-1. Connect the ac vtvm to the output of the attenuator set.

Rotate the Model 415B GAIN control fully clockwise and the RANGE switch to 0 DB. Set the input switch to XTAL 200 Ω and the METER SCALE switch to NORMAL.

Tune the audio oscillator to the 415B filter frequency as indicated by maximum deflection of the 415B meter. Adjust the audio oscillator output to obtain an indication of 0.03 volts on the ac vtvm. Note the indication on any convenient scale of the 415B. This indication will be used as a "reference".

Disconnect the ac vtvm and the audio oscillator. Set both 350B attenuators for 110 db attenuation. This is the only exception to the precaution given in the NOTE for Figure 4-1. Switch the 415B RANGE switch to 60 DB.

The indication on the 415B should be less than (to the left of) the "reference" indication noted above.

4-14 CALIBRATE EXPANDED SCALE

Connect the test equipment as shown in Figure 4-1. Connect the ac vtvm to the input of the attenuator set.

Rotate the Model 415B GAIN control fully clockwise and the RANGE switch to 0 DB. Set the input switch to XTAL 200 Ω and the METER SCALE switch to EXPAND.

Tune the audio oscillator to the 415B filter frequency as indicated by maximum deflection of the 415B meter. Check that the attenuator set is introducing at least 20 db of the attenuation and adjust the output of the audio oscillator to provide a full scale indication.

Attenuate the signal 4 db with the attenuator set. The 415B should now indicate 2 DB on the EXPANDED DB scale. If not, repeat the following procedure until a 4 db attenuation drops the meter indication from full scale to exactly the 2db mark: ---Note the meter deviation from the 2 db mark and adjust R33 to get an equal error on the other side of the 2 db mark. Readjust attenuator set and signal for a full scale deflection, then attenuate signal 4 db. Repeat until no additional adjustment is necessary.

4-15 CHECK -5 DB SWITCH

Connect the test equipment as shown in Figure 4-1. Connect the ac vtvm to the input of the attenuator set.

Rotate the Model 415B GAIN control fully clockwise and the RANGE switch to any convenient position. Set the input switch to XTAL 200 Ω and the METER SCALE switch to NORMAL.

Tune the audio oscillator to the 415B filter frequency as indicated by maximum deflection of the 415B meter. Check that the attenuator set is introducing at least 30 db of attenuation and adjust the output of the audio oscillator to provide a "full scale" indication.

Increase the input signal to the Model 415B 10 db by decreasing the setting on the attenuator. Switch the meter scale switch to the -5 DB position. The 415B indication should remain at the "full scale" point.

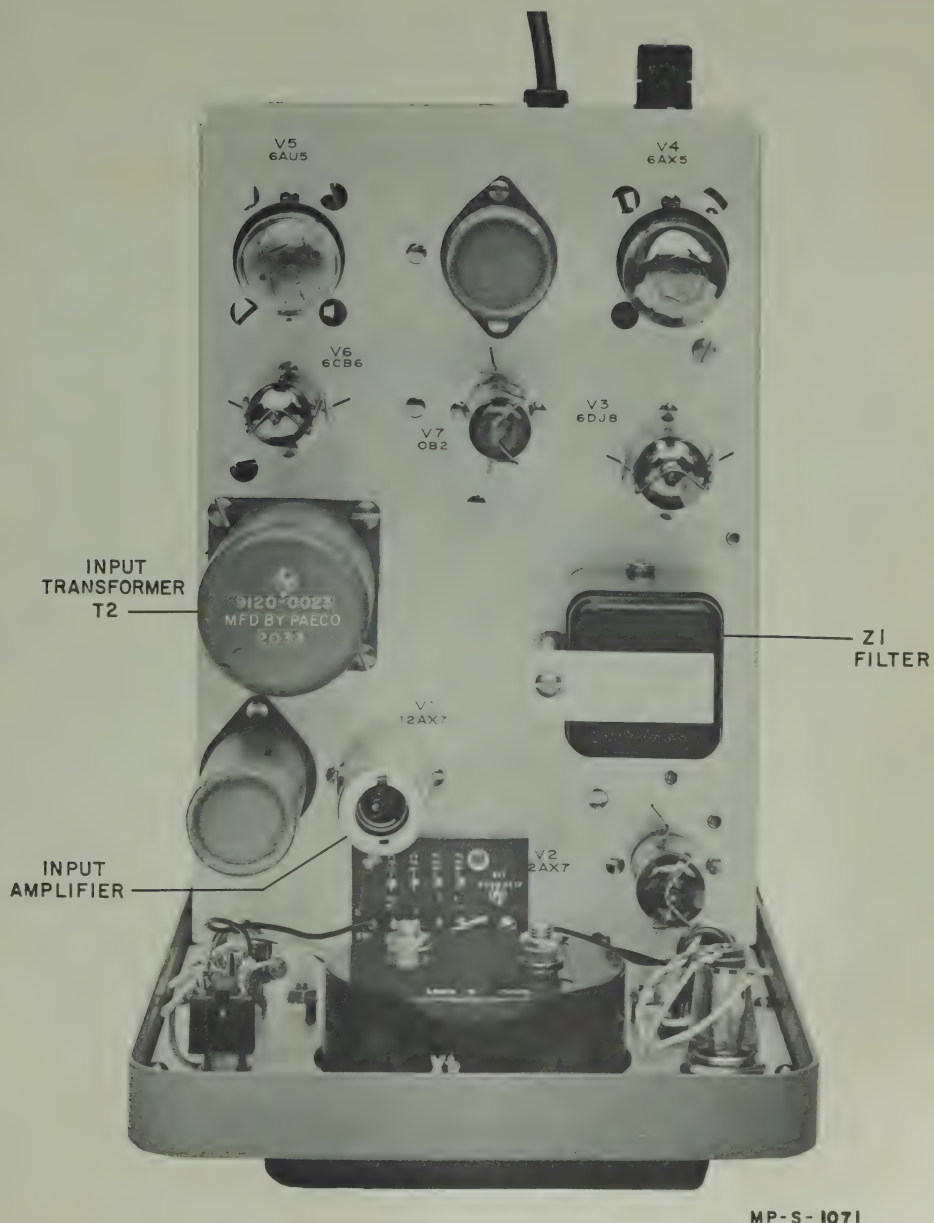


Figure 4-2. Model 415B Top View

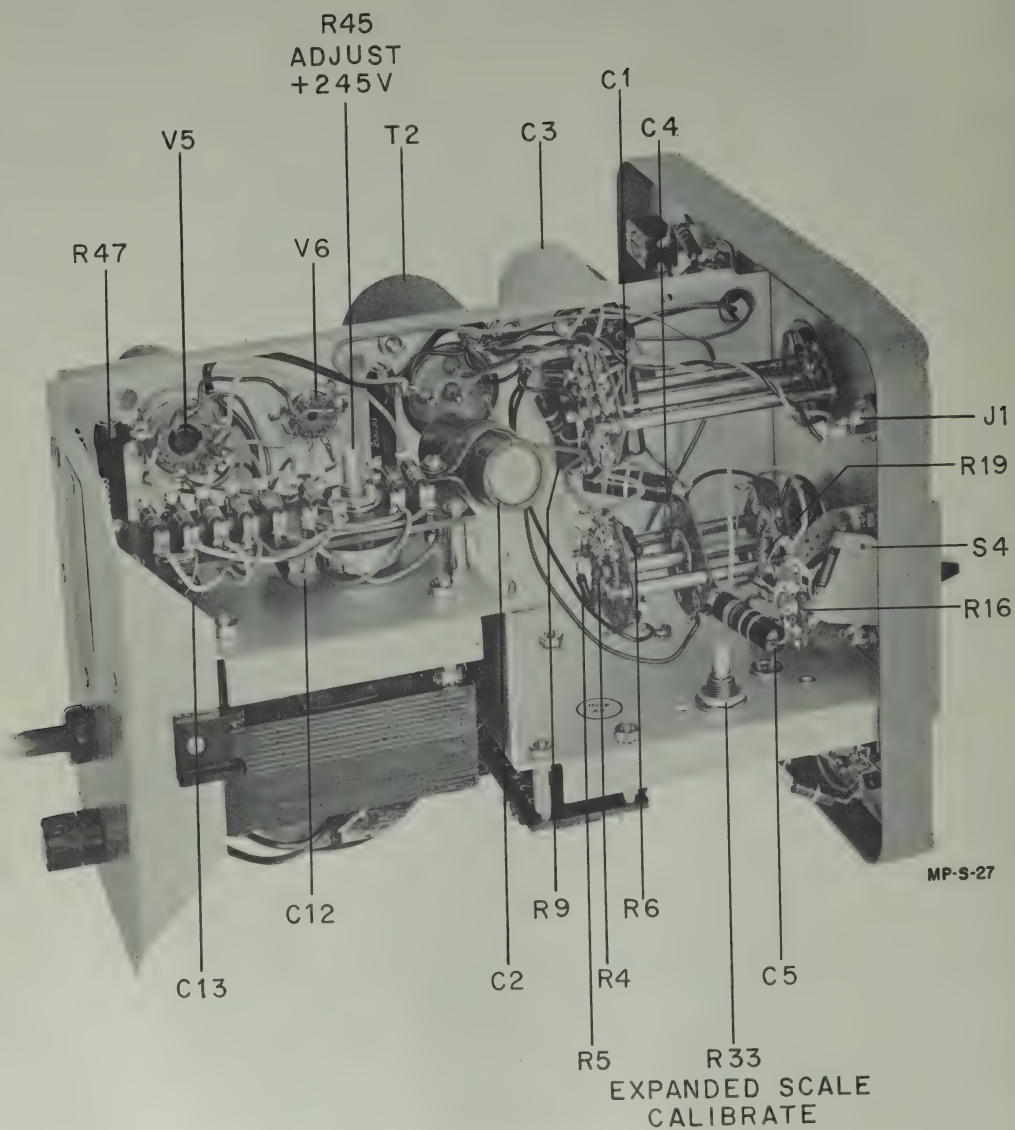
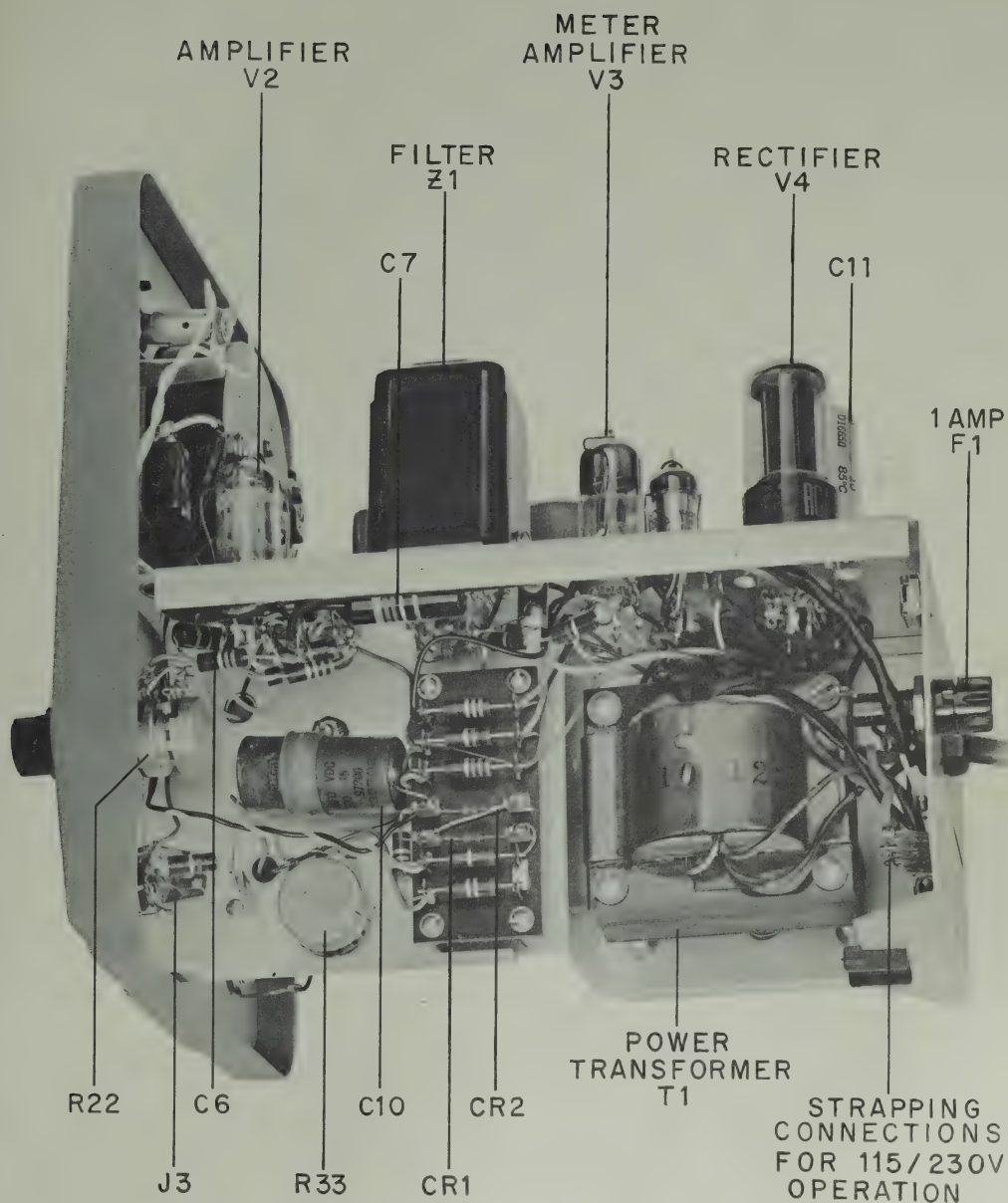


Figure 4-3. Model 415B Bottom View



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Figure 4-4. Model 415B Right Side

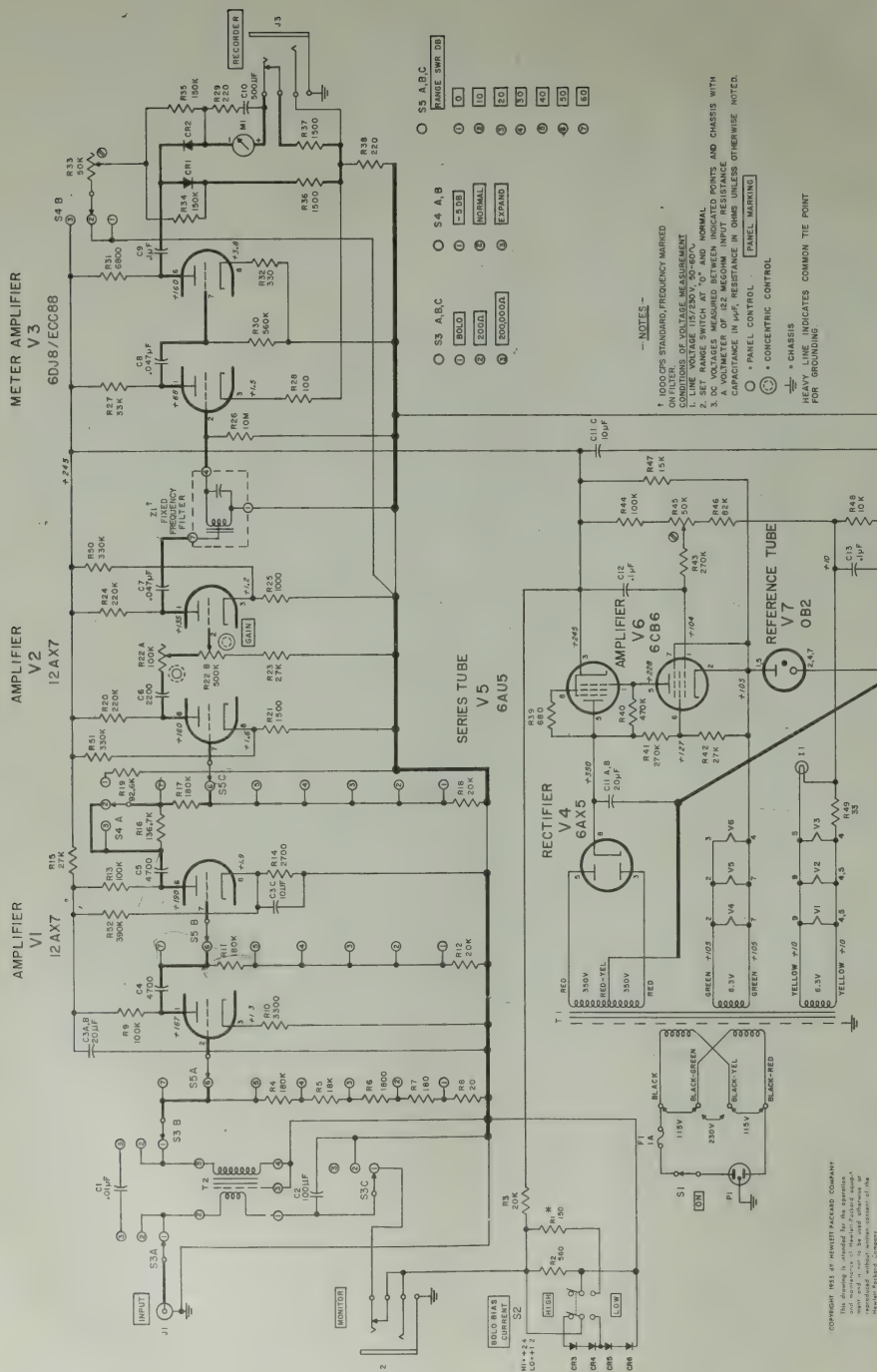


Figure 4-5. Model 415B Standing Wave Indicator

SECTION V

REPLACEABLE PARTS

5-1 INTRODUCTION

This section contains information for ordering replacement parts for the 415B Standing Wave Indicator.

5-2 TABLE OF REPLACEABLE PARTS

Table 5-1 lists replaceable parts in alpha-numerical order of their reference designators. At the end of the table are listed miscellaneous items such as knobs which have no assigned reference designators.

Detailed information on a part used more than once in the instrument is listed opposite the first reference designator applying to the part to appear in the table. Other reference designators applying to the same part reference the initial designator. The detailed information includes the following:

- 1) Full description of the part.
- 2) Manufacturer of the part in a five-digit code -- see list of manufacturers in appendix.
- 3) Total quantity used in the instrument (TQ column).
- 4) Recommended spare quantity for complete maintenance during one year of isolated service (RS column).

5-3 ORDERING INFORMATION

To order a replacement part, address order or inquiry either to your authorized Hewlett-Packard sales office or to

CUSTOMER SERVICE
Hewlett-Packard Company
395 Page Mill Road
Palo Alto, California

or, in western Europe, to

Hewlett-Packard S. A.
Rue du Vieux Billard No. 1
Geneva, Switzerland

Specify the following information on a part:

- 1) Model and serial number of the instrument. Be sure to include the three-digit serial prefix.
- 2) Φ stock number.
- 3) Circuit reference designator.
- 4) Description.

To order a part not listed in table 5-1, give a complete description of the part including its function and location in the circuit.

Table 5-1. Replaceable Parts (Sheet 1 of 5)

Ckt Ref.	Description	Mfr *	Φ Stock No.	TQ*	RS*		
C1	Capacitor: fixed, paper, .01 μ f $\pm 10\%$, 600 vdcw	56289	0160-0002	1	1		
C2	Capacitor: fixed, electrolytic, 100 μ f, 12 vdcw	56289	0180-0039	1	1		
C3A, B, C	Capacitor: fixed, electrolytic, 3 sections, 10 μ f -10% $+50\%$, 450 vdcw	00656	0180-0016	2	1		
C4, 5	Capacitor: fixed, paper, .0047 μ f $\pm 10\%$, 600 vdcw	56289	0160-0010	2	1		
C6	Capacitor: fixed, paper, .0022 μ f $\pm 10\%$, 600 vdcw	56289	0160-0007	1	1		
C7, 8	Capacitor: fixed, paper, .047 μ f $\pm 10\%$, 600 vdcw	56289	0160-0005	2	1		

Table 5-1. Replaceable Parts (Sheet 2 of 5)

Ckt Ref.	Description	Mfr *	Ⓜ Stock No.	TQ*	RS*		
C9	Capacitor: fixed, paper, 0.1 μ f $\pm 10\%$, 400 vdcw	56289	0160-0013	3	1		
C10	Capacitor: fixed, elect., 500 μ f, 15 vdcw	37942	0180-0001	1	1		
C11A,B,C	Same as C3A,B,C						
C12,13	Same as C9						
CR1, 2	Diode, germanium	73293	1910-0011	2	2		
CR3,4,5,6	Diode, silicon	07933	1901-0025	4	4		
F1	Fuse, cartridge: 1 amp, slow blow for 115V operation	71400	2110-0007	1	10		
	Fuse, cartridge: 1/2 amp, slow blow for 230V operation	71400		1	0		
I1	Lamp, incandescent: 6-8V, .15 amp, #47	24455	2140-0009	1	1		
J1	Connector, female: 52 ohms impedance (cabinet model)	91737	1250-0083	1	1		
	Connector, female: BNC type (rack model)	91737	1250-0001	1	1		
J2,3	Jack, telephone: for 3 conductor plug	82389	1251-0070	2	1		
M1	Meter	65092	1120-0044	1	1		
P1	Power cord	70903	8120-0050	1	1		
R1	Resistor: fixed, composition, 150 ohms $\pm 5\%$, 1 W	01121	0686-1515	1	1		
R2	Resistor: fixed, composition, 560 ohms $\pm 5\%$, 1 W Optimum value selected at factory Average value shown	01121	0689-5615	1	1		
R3	Resistor: fixed, wirewound, 20,000 ohms $\pm 10\%$, 10 W	35434	0816-0018	1	1		
R4	Resistor: fixed, deposited carbon, 180,000 ohms $\pm 1\%$, 1/2 W	19701	0727-0218	3	1		
R5	Resistor: fixed, deposited carbon, 18,000 ohms $\pm 1\%$, 1/2 W	19701	0727-0170	1	1		
R6	Resistor: fixed, deposited carbon, 1800 ohms $\pm 1\%$, 1/2 W	19701	0727-0112	1	1		
R7	Resistor: fixed, deposited carbon, 180 ohms $\pm 1\%$, 1/2 W	19701	0727-0050	1	1		

* See introduction to this section

Table 5-1. Replaceable Parts (Sheet 3 of 5)

Ckt Ref.	Description	Mfr *	Ⓢ Stock No.	TQ*	RS*		
R8	Resistor: fixed, deposited carbon, 20 ohms $\pm 1\%$, 1/2 W	19701	0727-0012	1	1		
R9	Resistor: fixed, deposited carbon, 100,000 ohms $\pm 1\%$, 1 W	19701	0730-0069	1	1		
R10	Resistor: fixed, composition, 3300 ohms $\pm 10\%$, 1 W	01121	0690-3321	1	1		
R11	Same as R4						
R12	Resistor: fixed, deposited carbon, 20,000 ohms $\pm 1\%$, 1/2 W	19701	0727-0173	2	1		
R13	Resistor: fixed, composition, 100,000 ohms $\pm 10\%$, 1 W	01121	0690-1041	2	1		
R14	Resistor: fixed, composition, 2700 ohms $\pm 10\%$, 1 W	01121	0690-2721	1	1		
R15	Resistor: fixed, composition, 27,000 ohms $\pm 10\%$, 1 W	01121	0690-2731	3	1		
R16	Resistor: fixed, deposited carbon, 136,700 ohms $\pm 1\%$, 1/2 W	19701	0727-0216	1	1		
R17	Same as R4						
R18	Same as R12						
R19	Resistor: fixed, deposited carbon, 92,600 ohms $\pm 1\%$, 1/2 W	19701	0727-0205	1	1		
R20	Resistor: fixed, composition, 220,000 ohms $\pm 10\%$, 1 W	01121	0690-2241	2	1		
R21	Resistor: fixed, composition, 1500 ohms $\pm 10\%$, 1 W	01121	0690-1521	3	1		
R22A, B	Resistor: variable, composition, dual section front sect., 500,000 ohms rear sect., 100,000 ohms	71590	2100-0071	1	1		
R23	Same as R15						
R24	Same as R20						
R25	Resistor: fixed, composition, 1000 ohms $\pm 10\%$, 1 W	01121	0690-1021	1	1		
R26	Resistor: fixed, composition, 10 megohms $\pm 10\%$, 1 W	01121	0690-1061	1	1		
R27	Resistor: fixed, composition, 33,000 ohms $\pm 10\%$, 1 W	01121	0690-3331	1	1		
R28	Resistor: fixed, composition, 100 ohms $\pm 10\%$, 1 W	01121	0690-1011	1	1		

* See introduction to this section

Table 5-1. Replaceable Parts (Sheet 4 of 5)

Ckt Ref.	Description	Mfr *	Stock No.	TQ*	RS*		
R29	Resistor: fixed, composition, 220 ohms $\pm 10\%$, 1 W	01121	0690-2211	2	1		
R30	Resistor: fixed, composition, 560,000 ohms $\pm 10\%$, 1 W	01121	0690-5641	1	1		
R31	Resistor: fixed, composition, 6800 ohms $\pm 10\%$, 1 W	01121	0690-6821	1	1		
R32	Resistor: fixed, composition, 330 ohms $\pm 10\%$, 1 W	01121	0690-3311	1	1		
R33	Resistor: variable, composition, linear taper, 50,000 ohms $\pm 20\%$	71590	2100-0013	1	1		
R34, 35	Resistor: fixed, composition, 150,000 ohms $\pm 10\%$, 1 W	01121	0690-1541	2	1		
R36, 37	Same as R21						
R38	Same as R29						
R39	Resistor: fixed, composition, 680 ohms $\pm 10\%$, 1 W	01121	0690-6811	1	1		
R40	Resistor: fixed, composition, 470,000 ohms $\pm 10\%$, 1 W	01121	0690-4741	1	1		
R41	Resistor: fixed, composition, 270,000 ohms $\pm 10\%$, 1 W	01121	0690-2741	2	1		
R42	Same as R15						
R43	Same as R41						
R44	Same as R13						
R45	Resistor: variable, composition, linear taper, 50,000 ohms $\pm 20\%$, 1/3 W	11237	2100-0084	1	1		
R46	Resistor: fixed, composition, 82,000 ohms $\pm 10\%$, 1 W	01121	0690-8231	1	1		
R47	Resistor: fixed, wirewound, 15,000 ohms $\pm 10\%$, 10 W	35434	0816-0013	1	1		
R48	Resistor: fixed, composition, 10,000 ohms $\pm 10\%$, 1 W	01121	0690-1031	1	1		
R49	Resistor: fixed, composition, 33 ohms $\pm 10\%$, 1 W	01121	0690-3301	1	1		
R50, 51	Resistor: fixed, composition, 330,000 ohms $\pm 10\%$, 1 W	01121	0690-3341	2	1		
R52	Resistor: fixed, composition, 390,000 ohms $\pm 10\%$, 1 W	01121	0390-3941	1	1		

* See introduction to this section

Table 5-1. Replaceable Parts (Sheet 5 of 5)

Ckt Ref.	Description	Mfr *	Ⓢ Stock No.	TQ*	RS*		
S1	Switch, toggle: SPST	04009	3101-0001	1	1		
S2	Switch, toggle: DPDT	04009	3101-0005	1	1		
S3A, B, C	Switch, rotary: 1 section, 3 positions	76854	3100-0114	1	1		
S4	Switch, lever: 3 positions, cabinet model, rack model	71590	3100-0113	1	1		
S5	Range Switch Assembly, includes C4, C5, R4 thru R8, R11, R12, R17, R18	28480	415B-19A	1	1		
T1	Transformer, power	98734	9100-0059	1	1		
T2	Transformer, input	98734	9120-0023	1	1		
V1,2	Tube, electron: 12AX7	80131	1932-0030	2	2		
V3	Tube, electron: 6DJ8/ECC88	80131	1932-0022	1	1		
V4	Tube, electron: 6AX5	80131	1930-0014	1	1		
V5	Tube, electron: 6AU5	80131	1923-0020	1	1		
V6	Tube, electron: 6CB6	80131	1923-0028	1	1		
V7	Tube, electron: OB2	80131	1940-0007	1	1		
Z1	Filter Assembly: 1000-cycle	28480	415B-42A	1	1		
	Filter, special frequency: specify the particular frequency desired between 315 and 700 cps but avoid multiples of 60 cps by at least 15 cps.	28480	415B-42B				
	Filter, special frequency: specify the particular frequency desired between 700 and 2000 cps but avoid multiples of 60 cps by at least 15 cps.	28480	415B-42C				
	<u>MISCELLANEOUS</u>						
	Cable, external	28480	41A-16E	1	0		
	Fuseholder	75915	1400-0084	1	1		
	Knob: lever	28480	G-74AA	1	0		
	Knob: GAIN (3/4 inch)	28480	G-74A	1	0		
	Knob: GAIN (with arrow)	28480	G-74L	1	0		
	Knob: RANGE, BOLO. CRYSTAL	28480	G-74N	2	0		

* See introduction to this section

APPENDIX **CODE LIST OF MANUFACTURERS (Sheet 1 of 2)**

The following code numbers are from the Federal Supply Code for Manufacturers Cataloging Handbooks H4-1 (Name to Code) and H4-2 (Code to Name) and their latest supplements. The date of revision and the date of the supplements used appear at the bottom of each page. Alphabetical codes have been arbitrarily assigned to suppliers not appearing in the H4 handbooks.

CODE NO.	MANUFACTURER	ADDRESS	CODE NO.	MANUFACTURER	ADDRESS	CODE NO.	MANUFACTURER	ADDRESS
00334	Humidial Co.	Colton, Calif.	07137	Transistor Electronics Corp.	Minneapolis, Minn.	47904	Polaroid Corp.	Cambridge, Mass.
00335	Westrex Corp.	New York, N.Y.	07138	Westinghouse Electric Corp.	Elmira, N.Y.	48620	Precision Thermometer and Inst. Co.	Philadelphia, Pa.
00373	Garlock Packing Co.	Camden, N.J.	07261	Avnet Corp.	Los Angeles, Calif.	49956	Raytheon Company	Lexington, Mass.
00456	Aerovox Corp.	New Bedford, Mass.	07263	Fairchild Semiconductor Corp.	Mountain View, Calif.	54294	Shallcross Mfg. Co.	Selma, N.C.
00779	Amp, Inc.	Harrisburg, Pa.	07910	Continental Device Corp.	Hawthorne, Calif.	55026	Simpson Electric Co.	Chicago, Ill.
00781	Aircraft Radio Corp.	Boonton, N.J.	07933	Rheem Semiconductor Corp.	Mountain View, Calif.	55933	Sonotone Corp.	Elmsford, N.Y.
00853	Sangamo Electric Company, Ordill Division (Capacitors)	Marion, Ill.	07980	Boonton Radio Corp.	Boonton, N.J.	55938	Sorenson & Co., Inc.	So. Norwalk, Conn.
00866	Goe Engineering Co.	Los Angeles, Calif.	08145	U.S. Engineering Co.	Los Angeles, Calif.	56137	Spaulding Fibre Co., Inc.	Tonawanda, N.Y.
00891	Carl E. Holmes Corp.	Los Angeles, Calif.	08358	Burgess Battery Co.	Niagara Falls, Ontario, Canada	56289	Sprague Electric Co.	North Adams, Mass.
01121	Allen Bradley Co.	Milwaukee, Wis.	08717	Sloan Company	Burbank, Calif.	59446	Telex, Inc.	St. Paul, Minn.
01255	Lifton Industries, Inc.	Beverly Hills, Calif.	08718	Cannon Electric Co.	Phoenix, Ariz.	61775	Union Switch and Signal, Div. of Westinghouse Air Brake Co.	Swissvale, Pa.
01281	Pacific Semiconductors, Inc.	Culver City, Calif.	08792	CBS Electronics Semiconductor Operations, Div. of C.B.S. Inc.	Lowell, Mass.	62119	Universal Electric Co.	Owosso, Mich.
01295	Texas Instruments, Inc.	Dallas, Texas	09026	Babcock Relays, Inc.	Costa Mesa, Calif.	64959	Western Electric Co., Inc.	New York, N.Y.
01349	The Alliance Mfg. Co.	Alliance, Ohio	09134	Texas Capacitor Co.	Houston, Texas	65092	Weston Inst. Div. of Daystrom, Inc.	Newark, N.J.
01561	Chassi-Trak Corp.	Indianapolis, Ind.	09250	Electro Assemblies, Inc.	Chicago, Ill.	66346	Wollensak Optical Co.	Rochester, N.Y.
01589	Pacific Relays, Inc.	Van Nuys, Calif.	09569	Mallory Battery Co. of Canada, Ltd.	Toronto, Ontario, Canada	70276	Allen Mfg. Co.	Hartford, Conn.
01930	Amercor Corp.	Rockford, Ill.	10214	General Transistor Western Corp.	Los Angeles, Calif.	70309	Allied Control Co., Inc.	New York, N.Y.
01961	Pulse Engineering Co.	Santa Clara, Calif.	10411	Ti-Tal, Inc.	Berkeley, Calif.	70485	Atlantic India Rubber Works, Inc.	Chicago, Ill.
02114	Ferrocube Corp. of America	Saugerties, N.Y.	10646	Carborundum Co.	Niagara Falls, N.Y.	70563	Amperite Co., Inc.	New York, N.Y.
02286	Cole Mfg. Co.	Palo Alto, Calif.	11236	CTS of Berne, Inc.	Berne, Ind.	70903	Belden Mfg. Co.	Chicago, Ill.
02660	Amphenol-Borg Electronics Corp.	Chicago, Ill.	11237	Chicago Telephone of California, Inc.	So. Pasadena, Calif.	70998	Bird Electronic Corp.	Cleveland, Ohio
02735	Radio Corp. of America Semiconductor and Materials Div.	Somerville, N.J.	11312	Microwave Electronics Corp.	Palo Alto, Calif.	71002	Birnbach Radio Co.	New York, N.Y.
02771	Vocaline Co. of America, Inc.	Old Saybrook, Conn.	11711	General Instrument Corporation Semiconductor Division	Newark, N.J.	71041	Boston Gear Works Div. of Murray Co. of Texas	Quincy, Mass.
02777	Hopkins Engineering Co.	San Fernando, Calif.	11717	Imperial Electronics, Inc.	Buena Park, Calif.	71218	Bud Radio Inc.	Cleveland, Ohio
03508	G.E. Semiconductor Products Dept.	Syracuse, N.Y.	11870	Melabs, Inc.	Palo Alto, Calif.	71286	Camluc Fastener Corp.	Paramus, N.J.
03705	Apex Machine & Tool Co.	Dayton, Ohio	12697	Claroat Mfg. Co.	Dover, N.H.	71313	Allen D. Cardwell Electronic Prod. Corp.	Plainville, Conn.
03797	Elidema Corp.	El Monte, Calif.	14655	Cornell Dubilier Elec. Corp.	So. Plainfield, N.J.	71400	Bussmann Fuse Div. of McGraw-Edison Co.	St. Louis, Mo.
03877	Transitron Electronic Corp.	Wakefield, Mass.	15909	The Daven Co.	Livingston, N.J.	71450	CTS Corp.	Elkhart, Ind.
03888	Pyrofilm Resistor Co.	Morristown, N.J.	16688	De Jur-Amsco Corporation	Long Island City 1, N.Y.	71468	Cannon Electric Co.	Los Angeles, Calif.
03954	Air Marine Motors, Inc.	Los Angeles, Calif.	16758	Delco Radio Div. of G. M. Corp.	Kokomo, Ind.	71471	Cinema Engineering Co.	Burbank, Calif.
04009	Arrow, Hart and Hegeman Elect. Co.	Hartford, Conn.	18873	E. I. DuPont and Co., Inc.	Wilmington, Del.	71482	C. P. Clare & Co.	Chicago, Ill.
04062	Elmenco Products Co.	New York, N.Y.	19315	Eclipse Pioneer, Div. of Bendix Aviation Corp.	Teterboro, N.J.	71528	Standard-Thomson Corp., Clifford Mfg. Co. Div.	Waltham, Mass.
04222	Hi-Q Division of Aerovox	Myrtle Beach, S.C.	19500	Thomas A. Edison Industries, Div. of McGraw-Edison Co.	West Orange, N.J.	71590	Centralab Div. of Globe Union Inc.	Milwaukee, Wis.
04298	Elgin National Watch Co., Electronics Division	Burbank, Calif.	19701	Electra Manufacturing Co.	Kansas City, Mo.	71700	The Cornish Wire Co.	New York, N.Y.
04404	Dymec Division of Hewlett-Packard Co.	Palo Alto, Calif.	20183	Electronic Tube Corp.	Philadelphia, Pa.	71744	Chicago Miniature Lamp Works	Chicago, Ill.
04651	Sylvania Electric Prods., Inc. Electronic Tube Div.	Mountain View, Calif.	21520	Fanstel Metallurgical Corp.	No. Chicago, Ill.	71753	A. O. Smith Corp., Crow Div.	West Orange, N.J.
04713	Motorola, Inc., Semiconductor Prod. Div.	Phoenix, Arizona	21335	The Fafnir Bearing Co.	New Britain, Conn.	71785	Cinch Mfg. Corp.	Chicago, Ill.
04732	Filttron Co., Inc. Western Division	Culver City, Calif.	21964	Fed. Telephone and Radio Corp.	Clifton, N.J.	71984	Dow Corning Corp.	Midland, Mich.
04773	Automatic Electric Co.	Northlake, Ill.	24446	General Electric Co.	Schenectady, N.Y.	72136	Electro Motive Mfg. Co., Inc.	Willimantic, Conn.
04870	P. M. Motor Co.	Chicago, Ill.	24455	G.E., Lamp Division	Nela Park, Cleveland, Ohio	72354	John E. Fast & Co.	Chicago, Ill.
05006	Twentieth Century Plastics, Inc.	Los Angeles, Calif.	24655	General Radio Co.	West Concord, Mass.	72619	Dialight Corp.	Brooklyn, N.Y.
05277	Westinghouse Electric Corp., Semi-Conductor Dept.	Youngwood, Pa.	24662	Grobet File Co. of America, Inc.	Carlstadt, N.J.	72656	General Ceramics Corp.	Kearney, N.J.
05347	Ultronic, Inc.	San Mateo, Calif.	26992	Hamilton Watch Co.	Lancaster, Pa.	72758	Girard-Hopkins	Oakland, Calif.
05593	Illumitronic Engineering Co.	Sunnyvale, Calif.	28880	Hewlett-Packard Co.	Palo Alto, Calif.	72765	Drake Mfg. Co.	Chicago, Ill.
05624	Barber Colman Co.	Rockford, Ill.	31173	G.E. Receiving Tube Dept.	Owensboro, Ky.	72825	Hugh H. Eby Inc.	Philadelphia, Pa.
05729	Metropolitan Telecommunications Corp., Metro Cap. Div.	Brooklyn, N.Y.	35434	Lectrohm Inc.	Chicago, Ill.	72928	Gudeman Co.	Chicago, Ill.
05783	Stratberg Engineering Co.	Santa Cruz, Calif.	37942	P. R. Mallory & Co., Inc.	Indianapolis, Ind.	72982	Erie Resistor Corp.	Erie, Pa.
06004	The Bassick Co.	Bridgeport, Conn.	39543	Mechanical Industries Prod. Co.	Akron, Ohio	73061	Hamson Mfg. Co., Inc.	Princeton, Ind.
06555	Beede Electrical Instrument Co., Inc.	Penacook, N.H.	40920	Miniature Precision Bearings, Inc.	Keene, N.H.	73138	Helipot Div. of Beckman Instruments, Inc.	Fullerton, Ind.
06812	Torrington Mfg. Co., West Div.	Van Nuys, Calif.	42190	Muter Co.	Chicago, Ill.	73293	Hughes Products Division of Hughes Aircraft Co.	Newport Beach, Calif.
07115	Corning Glass Works Electronic Components Dept.	Bradford, Pa.	43990	C. A. Norgren Co.	Englewood, Colo.	73445	Amperex Electronic Co., Div. of North American Phillips Co., Inc.	Hicksville, N.Y.
07126	Digitran Co.	Pasadena, Calif.	44655	Ohmite Mfg. Co.	Skokie, Ill.	73506	Bradley Semiconductor Corp.	Hamden, Conn.

From: F.S.C. Handbook Supplements
H4-1 Dated December 1961
H4-2 Dated December 1961

APPENDIX **CODE LIST OF MANUFACTURERS (Sheet 2 of 2)**

CODE NO.	MANUFACTURER	ADDRESS	CODE NO.	MANUFACTURER	ADDRESS	CODE NO.	MANUFACTURER	ADDRESS
74868	R.F. Products Division of Amphenol-Borg Electronics Corp.	Danbury, Conn.	82893	Vector Electronic Co.	Glendale, Calif.	95354	Methode Mfg. Co.	Chicago, Ill.
74970	E. F. Johnson Co.	Waseca, Minn.	83053	Western Washer Mfr. Co.	Los Angeles, Calif.	95987	Weckesser Co.	Chicago, Ill.
75042	International Resistance Co.	Philadelphia, Pa.	83058	Carr Fastener Co.	Cambridge, Mass.	96067	Huggins Laboratories	Sunnyvale, Calif.
75173	Jones, Howard B., Division of Cinch Mfg. Corp.	Chicago, Ill.	83086	New Hampshire Ball Bearing, Inc.	Peterborough, N.H.	96095	Hi-Q Division of Aerovox	Olean, N.Y.
75378	James Knights Co.	Sandwich, Ill.	83125	Pyramid Electric Co.	Darlington, S.C.	96256	Thordarson-Meisner Div. of Maguire Industries, Inc.	Mt. Carmel, Ill.
75382	Kulka Electric Corporation	Mt. Vernon, N.Y.	83148	Electro Cords Co.	Los Angeles, Calif.	96296	Solar Manufacturing Co.	Los Angeles, Calif.
75818	Lenz Electric Mfg. Co.	Chicago, Ill.	83186	Victory Engineering Corp.	Union, N.J.	96330	Carlton Screw Co.	Chicago, Ill.
75915	Littelfuse Inc.	Des Plaines, Ill.	83298	Bendix Corp., Red Bank Div.	Red Bank, N.J.	96341	Microwave Associates, Inc.	Burlington, Mass.
76005	Lord Mfg. Co.	Erie, Pa.	83330	Smith, Herman H., Inc.	Brooklyn, N.Y.	96501	Excel Transformer Co.	Oakland, Calif.
76210	C. W. Marwedel	San Francisco, Calif.	83501	Gavitt Wire and Cable Co., Div. of Amerace Corp.	Brookfield, Mass.	97464	Industrial Retaining Ring Co.	Irvington, N.J.
76433	Micamold Electronic Mfg. Corp.	Brooklyn, N.Y.	83594	Burroughs Corp., Electronic Tube Div.	Plainfield, N.J.	97539	Automatic and Precision Mfg. Co.	Yonkers, N.Y.
76487	James Millen Mfg. Co., Inc.	Malden, Mass.	83777	Model Eng. and Mfg., Inc.	Huntington, Ind.	97966	CBS Electronics, Div. of C.B.S., Inc.	Danvers, Mass.
76493	J. W. Miller Co.	Los Angeles, Calif.	83821	Loyd Scruggs Co.	Festus, Mo.	98141	Axel Brothers Inc.	Jamaica, N.Y.
76530	Monadnock Mills	San Leandro, Calif.	84171	Arco Electronics, Inc.	New York, N.Y.	98220	Francis L. Mosley	Pasadena, Calif.
76545	Mueller Electric Co.	Cleveland, Ohio	84396	A. J. Glesner Co., Inc.	San Francisco, Calif.	98278	Microdut, Inc.	So. Pasadena, Calif.
76854	Oak Manufacturing Co.	Chicago, Ill.	84411	Good All Electric Mfg. Co.	Ogallala, Neb.	98291	Sealectro Corp.	Mamaroneck, N.Y.
77068	Bendix Pacific Division of Bendix Corp.	No. Hollywood, Calif.	84970	Sarkes Tarzian, Inc.	Bloomington, Ind.	98405	Garad Corp.	Redwood City, Calif.
77221	Phaoston Instrument and Electronic Co.	South Pasadena, Calif.	85454	Boonton Molding Company	Boonton, N.J.	98734	Palo Alto Engineering Co., Inc.	Palo Alto, Calif.
77342	Potter and Brumfield, Div. of American Machine and Foundry	Princeton, Ind.	85474	R. M. Bracamonte & Co.	San Francisco, Calif.	98821	North Hills Electric Co.	Mineola, N.Y.
77630	Radio Condenser Co.	Camden, N.J.	85660	Koiled Kords, Inc.	New Haven, Conn.	98925	Clevite Transistor Prod. Div. of Clevite Corp.	Waltham, Mass.
77638	Radio Receptor Co., Inc.	Brooklyn, N.Y.	85911	Seamless Rubber Co.	Chicago, Ill.	98978	International Electronic Research Corp.	Burbank, Calif.
77764	Resistance Products Co.	Harrisburg, Pa.	86197	Cliffon Precision Products	Cliffon Heights, Pa.	99109	Columbia Technical Corp.	Palo Alto, Calif.
78189	Shakeproof Division of Illinois Tool Works	Elgin, Ill.	86684	Radio Corp. of America, RCA Electron Tube Div.	Harrison, N.J.	99313	Varian Associates	Pasadena, Calif.
78283	Signal Indicator Corp.	New York, N.Y.	87216	Philco Corp. (Lansdale Division)	Lansdale, Pa.	99515	Marshall Industries, Electron Products Division	Pasadena, Calif.
78471	Tilley Mfg. Co.	San Francisco, Calif.	87473	Western Fibrous Glass Products Co.	San Francisco, Calif.	99707	Control Switch Division, Controls Co. of America	El Segundo, Calif.
78488	Stackpole Carbon Co.	St. Marys, Pa.	88140	Cutler-Hammer, Inc.	Lincoln, Ill.	99800	Delevan Electronics Corp.	East Aurora, N.Y.
78553	Tinnerman Products, Inc.	Cleveland, Ohio	88220	Gould-National Batteries, Inc.	St. Paul, Minn.	99848	Wilco Corporation	Indianapolis, Ind.
78790	Transformer Engineers	Pasadena, Calif.	89473	General Electric Distributing Corp.	Schenectady, N.Y.	99934	Renbrandt, Inc.	Boston, Mass.
78947	Ucinite Co.	Newtonville, Mass.	89636	Carter Parts Div. of Economy Baler Co.	Chicago, Ill.	99942	Hoffman Semiconductor Div. of Hoffman Electronics Corp.	Evanston, Ill.
79142	Veeder Root, Inc.	Hartford, Conn.	89665	United Transformer Co.	Chicago, Ill.	99957	Technology Instrument Corp. of Calif.	Newbury Park, Calif.
79251	Wenco Mfg. Co.	Chicago, Ill.	90179	U.S. Rubber Co., Mechanical Goods Div.	Passaic, N.J.			
79727	Continental-Wirt Electronics Corp.	Philadelphia, Pa.	90970	Bearing Engineering Co.	San Francisco, Calif.			
79963	Zierick Mfg. Corp.	New Rochelle, N.Y.	91260	Connor Spring Mfg. Co.	San Francisco, Calif.			
80031	Mepco Division of Sessions Clock Co.	Morristown, N.J.	91418	Radio Materials Co.	Chicago, Ill.			
80120	Schnitzer Alloy Products	Elizabeth, N.J.	91506	Augat Brothers, Inc.	Athleboro, Mass.			
80130	Times Facsimile Corp.	New York, N.Y.	91637	Dale Electronics, Inc.	Columbus, Nebr.			
80131	Electronic Industries Association Any brand tube meeting EIA standards	Washington, D.C.	91662	Eico Corp.	Philadelphia, Pa.			
80207	Unimax Switch, Div. of W. L. Mason Corp.	Wallingford, Conn.	91737	Gremar Mfg. Co., Inc.	Wakefield, Mass.			
80248	Oxford Electric Corp.	Chicago, Ill.	91827	K F Development Co.	Redwood City, Calif.			
80294	Bourns Laboratories, Inc.	Riverside, Calif.	91921	Minneapolis-Honeywell Regulator Co., Micro-Switch Division	Freeport, Ill.			
80411	Acro Div. of Robertshaw Fulton Controls Co.	Columbus 16, Ohio	92196	Universal Metal Products, Inc.	Bassett Puate, Calif.			
80486	All Star Products Inc.	Defiance, Ohio	93332	Sylvania Electric Prod. Inc., Semiconductor Div.	Woburn, Mass.			
80583	Hammerlund Co., Inc.	New York, N.Y.	93369	Robbins and Myers, Inc.	New York, N.Y.			
80640	Stevens, Arnold, Co., Inc.	Boston, Mass.	93410	Stevens Mfg. Co., Inc.	Mansfield, Ohio			
81030	International Instruments, Inc.	New Haven, Conn.	93983	Insuline-Van Norman Ind., Inc. Electronic Division	Manchester, N.H.			
81415	Wilkor Products, Inc.	Cleveland, Ohio	94144	Raytheon Mfg. Co., Industrial Components Div., Receiving Tube Operation	Quincy, Mass.			
81453	Raytheon Mfg. Co., Industrial Components Div., Industr. Tube Operations	Newton, Mass.	94145	Raytheon Mfg. Co., Semiconductor Div., California Street Plant	Newton, Mass.			
81483	International Rectifier Corp.	El Segundo, Calif.	94148	Scientific Radio Products, Inc.	Loveland, Colo.			
81860	Barry Controls, Inc.	Watertown, Mass.	94154	Tung-Sol Electric, Inc.	Newark, N.J.			
82042	Carter Parts Co.	Skokie, Ill.	94197	Curtis-Wright Corp., Electronics Div.	East Paterson, N.J.			
82142	Jeffers Electronics Division of Speer Carbon Co.	Du Bois, Pa.	94310	Tru Ohm Prod. Div. of Model Engineering and Mfg. Co.	Chicago, Ill.			
82170	Allen B. DuMont Labs., Inc.	Clifton, N.J.	94682	Worcester Pressed Aluminum Corp.	Worcester, Mass.			
82209	Maguire Industries, Inc.	Greenwich, Conn.	95236	Allies Products Corp.	Miami, Fla.			
82219	Sylvania Electric Prod. Inc., Electronic Tube Div.	Emporium, Pa.	95238	Continental Connector Corp.	Woodside, N.Y.			
82376	Astron Co.	East Newark, N.J.	95263	Leecraft Mfg. Co., Inc.	New York, N.Y.			
82389	Switchcraft, Inc.	Chicago, Ill.	95264	Lercro Electronics, Inc.	Burbank, Calif.			
82647	Metals and Controls, Inc., Div. of Texas Instruments, Inc.	Athleboro, Mass.	95265	National Coil Co.	Sheridan, Wyo.			
82866	Research Products Corp.	Madison, Wis.	95275	Vitramon, Inc.	Bridgeport, Conn.			
82877	Retron Manufacturing Co., Inc.	Woodstock, N.Y.						

THE FOLLOWING H.P. VENDORS HAVE NO NUMBER ASSIGNED IN THE LATEST SUPPLEMENT TO THE FEDERAL SUPPLY CODE FOR MANUFACTURERS HANDBOOK.

0000 F	Malco Tool and Die	Los Angeles, Calif.
00001	Telefunken (c/o American Elite)	New York, N.Y.
0000 L	Winchester Electronics, Inc.	Santa Monica, Calif.
0000 M	Western Coil Div. of Automatic Ind., Inc.	Redwood City, Calif.
0000 N	Nahm-Bros. Spring Co.	San Leandro, Calif.
0000 P	Ty-Car Mfg. Co., Inc.	Holliston, Mass.
0000 T	Texas Instruments, Inc. Metals and Controls Div.	Versailles, Ky.
0000 U	Tower Mfg. Corp.	Providence, R.I.
0000 W	Webster Electronics Co., Inc.	New York, N.Y.
0000 X	Spruce Pine Mica Co.	Spruce Pine, N.C.
0000 Y	Midland Mfg. Co. Inc.	Kansas City, Kans.
0000 Z	Willow Leather Products Corp.	Newark, N.J.
000 A	British Radio Electronics Ltd.	Washington, D.C.
000 B B	Precision Instrument Components Co.	Van Nuys, Calif.
000 C C	Computer Diode Corp.	Lodi, N.J.
000 E E	A. Williams Manufacturing Co.	San Jose, Calif.
000 F F	Carmichael Corrugated Specialties	Richmond, Calif.
000 G G	Goshen Die Cutting Service	Goshen, Ind.
000 H H	Rubbercraft Corp.	Torrance, Calif.
000 I I	Birtcher Corporation, Industrial Division	Monterey Park, Calif.

From: F.S.C. Handbook Supplements
H4-1 Dated December 1961
H4-2 Dated December 1961

00015-21
Revised: 7 February 1962

9 August 65-4

-hp- MODEL 415B
STANDING WAVE INDICATOR
Serials Below 213-11683

NOISE REDUCTION

To reduce noise in the input stage of -hp- Model 415B Standing Wave Indicators, serials below 213-11683, change R10 to a resistor, fixed metal film 3.32K ohms, $\pm 1\%$, 1/8 watt, - hp- Part Number 0757-0433.

The parts list in the operating and service manual should be changed to show the new part.

F



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